STRUCTURAL GEOGRAPHY OF IRELAND

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ELEANOR BUTLER, M.A.

Structural Geography of Ireland

As Part of the Region of N.W. Europe

BY

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These few pages are an attempt to unlock for the young people of Ireland a little of the wonderful history of our planet which is recorded in broken fragments in the rocks of their country.

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Geological Survey Office,
14 Hume Street,
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I have read with great pleasure the geological section of Miss E. Butler's work on the geography of Ireland, and have been much struck by the way in which the most modern investigations have been utilised, and the results stated in an attractive and lucid style that will appeal to readers who are by no means specialists. There is no redundancy or "talking round the subject," such as frequently occurs in so-called popular books, and the work will undoubtedly attract its readers to the long history of Ireland before it was occupied by man, and thus will add yet further to the interest felt in a country on its way to free development.

GRENVILLE A. J. COLE, D.Sc., F.R.S.,
Professor of Geology in the College of Science for Ireland, and Director of the Geological Survey of Ireland.

[*Since these pages were made ready for the printers, Professor Cole, to whom Irish Geography is so indebted, has passed away, leaving Ireland in particular, and the world of Science in general, the poorer for his loss. I cannot let the pages appear without a special acknowledgment of my indebtedness to him for the valuable notes which he made for me when reading the manuscript. Most of these are now embodied in the text.—E. B.*]

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STRUCTURAL GEOGRAPHY OF IRELAND

As Part of the Region of N.W. Europe

CHAPTER I.

THE OLDEST ROCKS.

LONG, long ago, where Ireland now stands firm-rooted in the ocean, there was no land, but only a vast expanse of sea. That sea extended over the site of the present Great Britain and over much of the present Europe. On its margins rose stretches of rocky wastes, down from which flowed rivers, carrying in their waters sand and mud from the land, even as the rivers do to-day, and depositing these on the sea-floor, the sand nearer the edge, as always happens, and the mud farther out to sea.

These materials went on accumulating, layer by layer, on that great sea-floor, for untold ages; and the layers pressed each other down by their great weight; and the weight of the water above them pressed them too, and the natural cements out of the sea-water helped to bind them together, until what was once sand and mud became hardened into solid rock. That rock forms the lowest down foundation of Ireland to-day and of Great Britain and Europe too.

Layer after layer of other rock has been piled up over it. Hot, molten matter from beneath the earth-crust has burst through it; but still that older rock itself remains; and, in the movements of the earth's surface, parts of it have been thrust up so high as to be now mountains. We can see it exposed to view in Donegal, and in Mayo and Sligo. It is a gleaming, greyish-coloured rock easily split into flakes. One can notice in it slaty layers which are probably due to the great pressure which it has undergone. It is called **schist** from a Greek word meaning "split," because it will split easily into thin scales. With the schist is a rock called **gneiss.** Though the gneiss exists in layers, like the schist, it was not laid down by sediment, but must have welled up in molten form from beneath, and then, mixing with the schist, some of which it melted, cooled down into the hard banded rock which it is to-day.

Schists, similarly associated with gneiss, also occur in the great mountain masses of North-west Scotland and in those of Scandinavia and of Eastern Canada. Scientists can find in these rocks no traces of the remains of either animal or vegetable life; and, therefore, it looks as if they date from a time before plants or animals inhabited the sea where they were laid down, or the land from which the rivers brought the sediments that formed them.

When these ancient schists were upheaved and formed solid land, the rains beat on them, and rivers flowed down from them as previously from the old rocky sea-margins; and so sands and mud were deposited around their edges, while farther out to sea, where the water was clearer, tiny creatures which had been called into life in the deep lived and

perished, their bodies and shells falling as sediment to the sea-floor. In time all these sediments too became solid rock, and they are the next oldest rocks which we find in Ireland. They appear at the surface on the flanks of the Leinster mountains from Bray to Waterford. Some of them have also been stripped of the later rock, which for a long time overlay them, on the summits of the Comeragh, Slieve Bloom and Galtee Mountains; and a great mass of them exists close beneath the surface in the district extending from Longford north-east to the sea at County Down.

The sands of these old seas have been compressed into what is called **grit,** a sandstone often coarse and giving sharp rock edges when eaten out by the weather; or they have been cemented into **quartzite;** and the mud deposits have been compressed into **flags, slates and shales.** Quartzite is so hard that it breaks off in sharp fragments when attacked by the weather, instead of crumbling away smoothly like other rocks. The great resisting peaks of Croagh Patrick and of the Twelve Bens in Connemara, of Errigal in Donegal, and of the Sugar Loaf in Wicklow are mountains of quartzite thus carved out by the weather.

This second oldest set of rocks is very largely represented in Wales. Now the old name of Wales is "Cambria," and so the lowest down layers of these rocks are called **Cambrian;** but the middle and later layers are called by another Welsh name, **Silurian,** from the district in South Wales inhabited long ago by a Welsh tribe called the "Silures"—a tribe whose name lives in history for the sturdy resistance which they offered to the invading Romans nineteen centuries ago.

Plate I.—Traces of Organic Things found in Cambrian and Silurian Rocks.

Fig. 1.

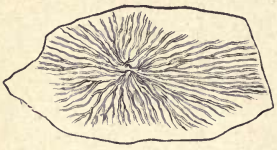


Fig. 2.

Fig. 3.

Fig. 4.

Figs. 1 and 2.—Impressions found in the rocks round Bray Head, Co. Wicklow. (Cambrian Period.) If these are remains of living organisms (which is doubtful) they are among the most ancient yet found.

Fig. 3.—Fossil of three-lobed fish (half natural size) from Cambrian rocks. Trilobites, as these fish are called, already began to appear in the Cambrian Period, and are very common in the Silurian, and more developed. They are interesting as representing a form of life which, though very abundant in early Palæozoic times, died out about the end of the Palæozoic Era.

Fig. 4.—(*a*) Fossil shell from Cambrian Rocks (half natural size). (*b*) Similar shell distorted by cleavage. These fossil shells are of interest as representing a form of life which had already shown itself in the Cambrian Period, which was very abundant in the Silurian, and which has survived down to our day.

In Ireland the rocks of Howth promontory and of the district from Bray southwards to Wicklow town are classed as Cambrian, and again a band of rock stretching from Cahore Point south-west to beyond Wexford town; but the other rocks mentioned above among the second oldest are classed as Silurian.

Cambrian rocks are the oldest which contain any well-marked remains of living organisms. But among the traces of life found in them are primitive types of almost every kind of invertebrate animal life, that is, of backbone-less animals; and it may be that still earlier forms of these primitive types will one day be traced in still older rocks.

The traces of life existing in Silurian rocks are somewhat more developed. Plate I. shows fossils found in Cambrian and Silurian rocks.

For convenience scientists now use the term **Pre-Cambrian** to signify the oldest rocks of all those formed by sediments, that is, the ancient schists in which, as we saw, no well defined traces of living organisms have yet been detected.

When these second oldest rocks, which we can now speak of as Cambrian and Silurian, had been laid down, some immense forces caused great wrinkles to form on the earth's surface. In our part of the globe these wrinkles ran in the direction north-east and south-west, and they thrust high up from beneath the sea great areas, which now form the Scandinavian mountains, the mountains of North-west Scotland, and, in Ireland, the great mountains of Donegal, Mayo and Connemara, the Leinster range, and the mountains running from Newry north-east into County

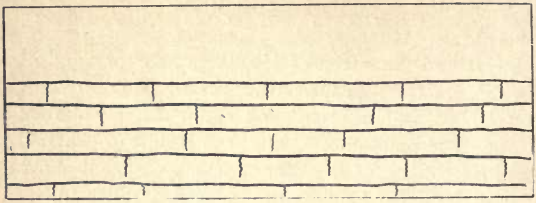


Fig. A. BEFORE UPHEAVAL.

Sedimentary rock in horizontal strata, as laid down on the ocean floor.

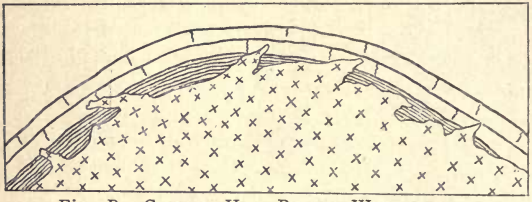


Fig. B. GRANITE HILL BEFORE WEATHERING.

Here the strata shown in Fig. A have been thrust up by a folding of the earth crust. Molten Granite has filled up the arch and altered the layers of rock with which it came in contact.

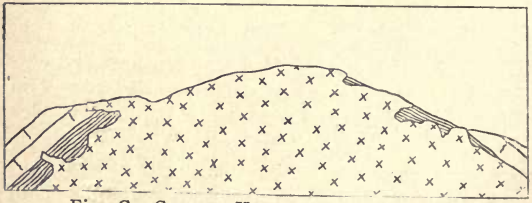


Fig. C. GRANITE HILL, AFTER WEATHERING.

The action of the weather, continued over long ages, has stripped the overlying strata from the summit, so that the solidified granite is now laid bare. The sedimentary rock still remains on the flanks of the hill. A very good example of this can be seen at the Vico bathing place, Dalkey, where large masses of mica-schist stand almost in an upright position flanking the massive granite, of which the hills at the back are composed.

Down, and terminating in Slieve Croob. As the wrinkles ran in the direction north-east and south-west, so the trend of the mountains formed by them remains to this day north-east and south-west. The arches of the earth-crust, formed by these foldings, became filled with molten rock from the interior. But the molten rock could not find its way out, except by a few occasional cracks, to the surface through all the thick layers of sedimentary rock* that over-lay it; so it cooled and grew solid within the arches of the earth-wrinkles, and it forms to-day the **Granite** core of the Leinster range, of the Ox Mountains, of the mountains of Connemara and Donegal and Newry, and of the mountains of Scotland and of Norway. However, though the molten matter from beneath was unable to force its way out to the surface, except through an occasional split, it greatly affected the rock against which it pressed from below, melting the under layers of it by its immense heat, and mingling with their substance. That is why, when we now examine places where granite pressed against the older sedimentary rock, we find that rock altered to **mica schist,** the shiny substance, mica, having developed out of the shales in the altering processes.

On the bathing strand at Dalkey, south of Dublin, an excellent example of this alteration can be seen. Great flags of mica schist stand almost upright, flanking the granite mass of which the hills at the back are composed.

The surface of the granite which filled up the arches of the old earth wrinkles is now laid bare on the mountain tops, for the weather has attacked and

* Rocks formed by sediment deposited in the sea or along rivers are called " Sedimentary Rocks."

eaten off the rock which formerly covered it. In fact, all along the Leinster chain from Dalkey south-west through County Wicklow and Carlow, to beyond the Nore in County Kilkenny, a distance of over seventy miles, the granite core of the mountains is laid bare along the mountain ridges; while, at both the eastern and western sides of the range, a strong flanking of mica schist remains.

Sometimes the mica schist is so hard and firm-set that it can be cut into great blocks for building purposes. At Glendalough, over the main doorway of the ruin of St. Kevin's Church, now thirteen centuries old, one can see an immense block of this stone. With all its parallel foldings it looks more like a beam of wood than a block of stone.

Granite is very largely used for building purposes. It is especially suitable for the building of quays and harbour walls; for, unlike the more common kinds of rock, it is not easily eaten away by water. Dún Laoghaire Harbour, for instance, is built of great blocks of granite quarried from the side of Dalkey Hill.

Granite is a very interesting rock to examine. The word **granite** itself means "consisting of grains"; and granite, we can see, has a granular constitution. When we examine it closely we find that it consists of three different materials. Firstly, there are small flakes of shiny rock, which can be easily removed with a penknife. This shiny substance is called *mica*, from a Latin word meaning "to glitter." Secondly, there are what look like tiny flattened bricks of a coloured rock, sometimes pink, sometimes grey, according to the kind of granite. These are *feldspar* (i.e., field-spar); and they, with the mica are held together by

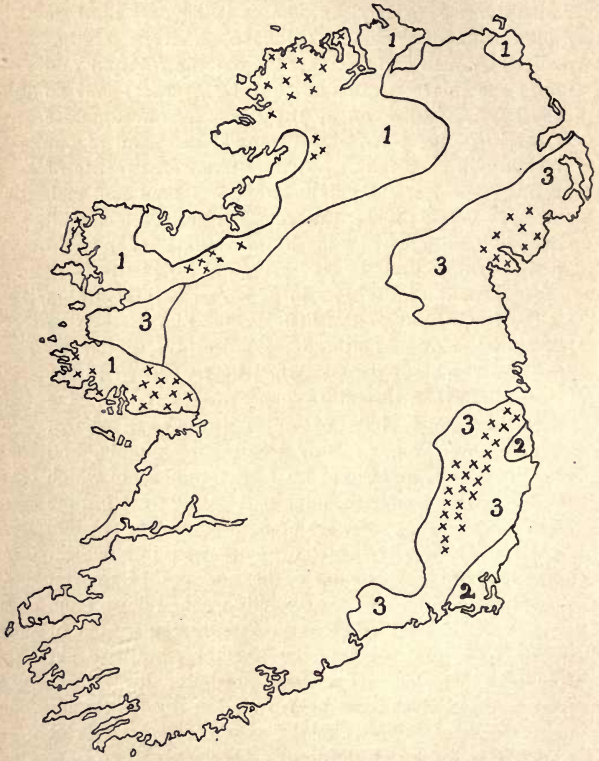
a third substance, a hard, transparent kind of rock called *quartz*. Quartz, as well as being very hard, is quite insoluble in ordinary acids; so, when the weather attacks granite and decomposes out the feldspar and mica, the quartz grains are set free intact, and so they are washed down by the rivers and accumulate at the sea edge to form the familiar sea-sand of our strands and sand-hills. But the other constituents of granite—the mica and feldspar—form mud and rich clay, for they both contain alumina and potash, and mica, in addition, contains iron and magnesium; and all these admixtures in clay are good for plants.

On account of the way in which granite weathers by the falling out of the little grains of quartz from between the other materials, granite hills, and even separate blocks of granite when long exposed to the weather, have a graceful, rounded appearance. On the other hand, hills of quartzite have a sharp, irregular appearance. Bray Head, for example, and Howth summit, and Sugar Loaf Mountain, all of which are formed of quartzite, have quite a different outline from Three Rock Mountain, and from the Dublin Mountains generally, which are mostly granite domes. Yet quartzite is made up of little grains of quartz. Probably the grains were originally washed down from granite hills. But whereas in granite the grains of quartz only bind the feldspar together, and are set free when it decomposes, in quartzite, the quartz grains themselves are held together by a strong quartz cement. That explains why the two kinds of rock are acted on so differently by the weather.

People who live near any of the mountain regions mentioned in this chapter will be able to see these things for themselves. Others will have plenty to

Plate III.

Map of Ireland Showing Roughly Where the Oldest Mountains are Situated.



1. Gneiss and schist with Granite core. 2. Cambrian Rocks. 3. Silurian Rocks with Granite core. The crosses show where Granite now appears at the surface.

In the Mourne district some of the Granite is of much more recent age.

see in their own districts when we come to later chapters. For we have not yet finished with the birth of Ireland. We leave her still part of a great northern continent; but we have seen some of her big bones formed—namely, the Leinster chain, and the mountains of Newry, Donegal and Connaught. The story of the birth of the South-west of Ireland, and of the Central Plain, will occupy us next.

CHAPTER II.

OLD RED SANDSTONE AND LIMESTONE.

THE great north-east and south-west earth foldings which, as we have seen, gave Ireland the Leinster Range, and the mountains of Connemara, Mayo, Donegal, etc., and which gave Highland Scotland and Norway their back-bone of mountains, are generally called the **Caledonian** foldings, because so large an area ridged up by them remains in Highland Scotland. So, too, the broad mass of land upheaved at the time of these foldings is spoken of as the Caledonian Continent. Caledonia was an ancient name of Scotland, much as Hibernia was of Ireland, and Cambria of Wales. The name is still often used in poetry. Byron, it will be remembered, addresses Scotland with the words:—

"Hail, Caledonia, stern and wild."

The Caledonian continent must have stretched eastwards into north-west Europe on the one hand, and away towards North America on the other, so that Ireland was part of it, not an island as she is to-day. On this old continent the weather acted for long

ages, wearing away the tops of the mountain foldings, and often exposing the underlying granite. In the hollows of the continent fresh-water lakes formed, chiefly in the southern half of the present Ireland; but some also formed in the northern half of Ireland, and in the areas between the Caledonian foldings in Scotland. But the great mountains which had been upheaved remained land—the mountains of Leinster, Connemara, Mayo, Donegal and Newry. Firm land must also have still remained away to the south and west beyond Cork and Kerry, where only the ocean is now. The Irish area must thus have been in the interior of a great continent; and so, desert conditions probably prevailed. By the crumbling away of the rocks under the attacks of the weather, great quantities of sand and mud were washed down, and deposited on the lake floors. Large quantities were also spread out upon the land surface by river floods and by winds, as happens on the verge of the Sahara to-day. These deposits, often thousands of feet thick, form the great masses of red sandstone and reddish flags, slate and conglomerate, which appear at the surface in the mountains of Cork, Kerry, Tipperary and Waterford to-day. A mass of the same kind of rock appears on the borders of Sligo and Roscommon, and a much larger mass in Ulster in the high ground between Lough Erne and Dungannon. Traces of an oxide of iron which must have been present in the lake waters, and which helped to cement the grains of these rocks together, have tinged them all a dark red. Sandstone is the rock most in evidence among them; therefore, the name "Red Sandstone" is loosely applied to the whole system. And because a much more recent deposit of

red sandstone is found in other places, as for instance, round Belfast Lough in Ireland, and in Cheshire in England, the term "Old" is applied to these older deposits. That explains the full name, **Old Red Sandstone System,** which is applied to the great mass of rock that forms the bones of South-west Ireland to-day.

Most of the rocks in the Devonian Peninsula in England were laid down at this time; and so the period of Old Red Sandstone is often spoken of as the **Devonian** Period. The traces of animal life found in the Old Red Sandstone rocks of Ireland and of Scotland consist of the remains of fresh-water fish, such as ganoids shown in Fig. 5, Plate IV.

That is how we know that these rocks must have been formed in fresh water lakes. But the Old Red Sandstone of Devon must have been formed under the sea, for it contains the remains of corals and sea-fish.*

* For the suggestion that much of the Irish Old Red Sandstone must have been laid down *on the land surface* by river floods and by winds is due to Professor Cole. The idea does not seem to have occurred to the older geologists; they regarded the whole Old Red Sandstone System in Ireland as lake floor deposit.

Professor Cole, referring to the Irish Old Red Sandstone, in his book, *Ireland the Outpost,* writes :—

"Throughout the Devonian Period, denuding forces were active on the surface of the Caledonian continent, and semi-arid conditions are believed to have prevailed. In desert-areas reddish and purplish sandstones were formed, where the waste products accumulated as broad cones at the feet of the decaying hills. Occasional floods, operating over wide areas of sun-dried detritus, spread beds of pebbles across the low-lands, and here and there more regularly stratified sands and muds were laid down in shallow lakes. These Devonian deposits are now cemented into rocks of high resistance, and the whole system of strata is styled the Old Red Sandstone."

(*Ireland the Outpost.* Oxford University Press, p. 12.)

PLATE IV.—SPECIMENS OF FAUNA AND FLORA OF THE OLD RED SANDSTONE PERIOD.

Fig. 5.

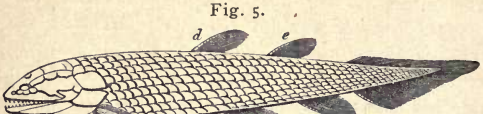


Fig. 7.

Fig. 6.

Fig. 8.

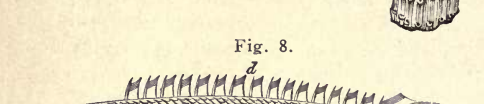


Fig. 5.—Fossil Fish from Old Red Sandstone Rocks. (*a*) One of the fringed pectoral fins. (*b*) One of the ventral fins. (*c*) Anal fin. (*d*) and (*e*) Dorsal fins.

This is the earliest known type of fish. It was protected by a bony armour composed of shiny scales. That is why geologists have named it *Ganoid* (Greek, ganos = splendour). In Fig. 8 above is shown one of the few modern representatives of these early armour-plated fish.

Figs. 6 and 7.—Plant impressions found in the Upper Old Red Sandstone, Co. Kilkenny.

Fig. 8.—Polypterus—an armour-coated fish which inhabits the Nile and other African rivers to-day. (*a*) One of the fringed pectoral fins. (*b*) One of the ventral fins. (*c*) Anal fin. (*d*) Dorsal fin or row of finlets.

Well-developed traces of plant life occur in the Old Red Sandstone System of rocks. Among them are the imprints of large ferns, mosses and reed-like plants, some of which are shown in the picture, Figs. 6 and 7.

During all this time for some reason the land must have been slowly sinking, so that the lakes of the Caledonian continent eventually became sea-inlets; and in time the sea spread over all the southern part of that old continent, gradually covering all of the Irish area south of the Donegal mountains, except the few higher groups of mountains, such as those of Connemara and Wicklow, some of whose tops still remained above water as archipeligoes, or possibly as promontories of the old continent. The same sea covered nearly all of England, and spread over the site of the present continent of Europe, covering Belgium and the Rhine country as far as Westphalia in Germany. We know this, because beds of limestone, like that which covers the central plain of Ireland, extend over all these regions. Now, if a fragment of this limestone be examined carefully under the microscope, it will be found to consist almost entirely of corals and of the shells and other calcareous remains of sea animals, all compressed and cemented together into solid stone. If some strong vinegar be dropped on the stone, the stone will be seen to fizz on the surface, and give off a gas just as sea-shells would if treated in the same way. Such a deposit could only be laid down on a sea floor; and a like deposit is being accumulated on the ocean floors to-day. When the limestone was laid down, the area where it exists must have been well out to sea; because near the coasts it is sand and mud from

the shore which would have accumulated, and not limestone. As a matter of fact, towards the edge of the limestone area, there occur beds of sandstone and shale, that is rocks formed from the sediment washed down from the land; and these beds must mark the edge of the sea in whose depths the great limestone deposits were laid down.

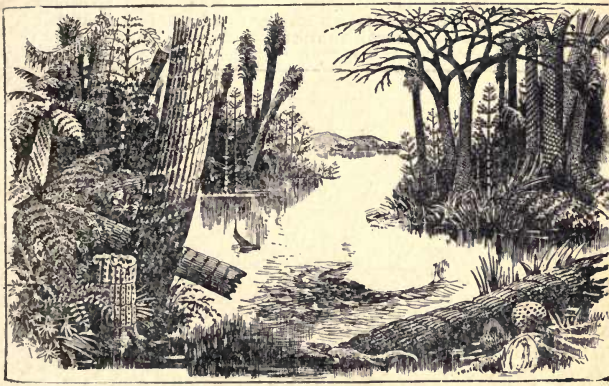
Overlying these limestones, oftenest near their edges, beds of coal appear. Great marshy areas, like shallow lakes, must have formed near the ocean's edge; and these must have become filled with a luxuriant vegetation of ferns, tall mosses and reed-like plants, such as will flourish only in a moist locality not visited by a severe winter cold. These plants, falling upon each other, century after century, and sending forth new growths, covered the ground with a thick bed of vegetable matter—fallen leaves, old plant-stems, roots, branches, etc. Unlikely as it appears, these great basins of once luxuriant vegetation form the coal seams of to-day* But the coal seams are to-day covered over with layers of shale and sandstone, which shows that the area covered by these rich forests must have again sunken and become sea floor. Over this floor, mud and sand washed down from the adjoining land, were laid down until their weight, and the weight of the water over them, compressed the masses of old vegetation into the black substance which we know as coal.

The great mass of limestone, which extends from the west of Ireland eastward through Europe to beyond the Rhine, is overlain by abundant coal fields, chiefly near its northern edge and wherever it flanks

* See illustrations: The Beginning of Coalfields (p. 27), Tree Ferns in the World To-day (p. 44).

the older mountains. For this reason the whole deposit is spoken of as **carboniferous.** The Latin word *carbo* means coal; and the word *carboniferous*, therefore, means coal-bearing. The period during which these deposits were laid down is called the **Carboniferous Period;** and we can judge of the great length of the

PLATE V.—THE BEGINNING OF COALFIELDS.



period when we learn that in some places the deposit reaches a thickness of six thousand feet. Towards the end of that long period the sea floor must have been gradually tilted up, what had been open sea becoming in succession sea shore, marshy land, and again shallow sea. We know this, because the carboniferous limestone is largely overlain by beds of shale and sandstone, including coal; and these formations tell a tale of shallow seas and forest-clad land.

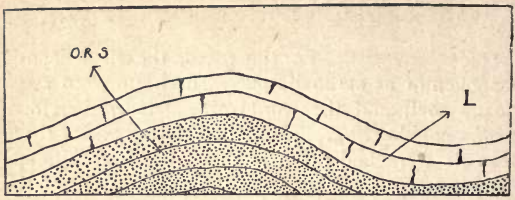


Fig. A.

LIMESTONE OVERLYING OLD, RED SANDSTONE CONFORMABLY.
L = Limestone; O.R.S. = Old Red Sandstone.

It is clear that the Limestone strata here were laid down while the Old Red Sandstone was yet in a horizontal position, and that the folding which thrust both deposits up must have occurred after the laying down of the Limestone.

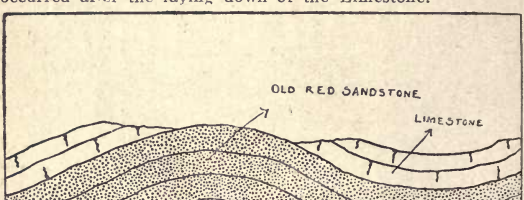


Fig. B.

Limestone strata remaining in the downfolds, while the weather has eaten them away from the upfolds. It is thus that the Limestone remains in the floor of the Munster valleys, while Old Red Sandstone appears on the mountain ridges.

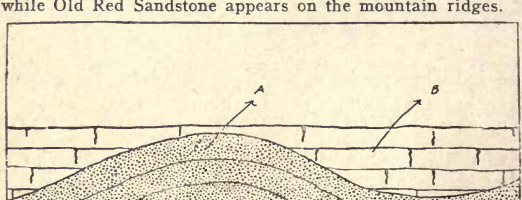


Fig. C. STRATA OF ROCK OVERLYING OTHER STRATA UNCONFORMABLY.

It is clear that the strata marked A would have been arched up before the strata marked B were deposited; but it is not thus that the Limestone in the southern valleys meets the Old Red Sandstone. It is thus, however, that the Old Red Sandstone and the Limestone jointly meet the Silurian strata.

Finally, the central plain of Ireland was definitely upheaved into dry land; and so was the north of England and Lowland Scotland. The rest of Scotland, it will be remembered, as well as the mountains of Donegal, Connemara and Leinster had, in part, remained above water all the time. The proof of this is that one can still trace the sea-edge deposits of that period up along their sides. For instance, on the southern side of Barnesmore, in South-east Donegal, one can notice the beds of limestone gradually growing thin, and eventually giving way to beds of sand and gravel, which must have been shore deposits.

About the time when the wide sea-floor of what we can now call the Carboniferous Sea was being upheaved into dry land again, another series of great earth-foldings occurred; or it might be that these foldings caused the upheaval. This time the pressure must have come from the south, for the folds ran east and west. The mountains of Brittany, in the west of France, are due to these foldings. In England the same foldings raised the earth-wrinkle which forms the present high peninsula of Devon and Cornwall. In Ireland they gave all the mountains of the south-west, from Dungarvan, in Waterford, to the sea at Kerry.

These foldings are sometimes called Armorican, because they are so well marked in Brittany, whose ancient name is Armorica. Sometimes they are called by other names, according to the different regions upheaved by them. But for us the best name for them is "Cork-and-Kerry" foldings, so marked are they in the counties of Cork and Kerry.

The same forces, which produced these "Cork-and-Kerry" foldings, extended northwards through the

Irish area. In Tipperary and Offaly they thrust up the Silvermine and the Slieve-Bloom mountains. If these mountains do not run exactly east and west, like the Galtees and the Reeks, it is because the foldings, which produced them, met with the older hard ridge of the Leinster Chain, and so were forced to accommodate themselves somewhat to it, which they did by bending a bit in its direction. The same "Cork-and-Kerry" foldings, too, thrust Clare into a great table-land, and ridged up the Slieve Aughty and the Slieve Bernagh mountains at its east. They also thrust up the great mass of mountain limestone between Bundoran and Lough Gill.

We can know that all these mountains were upheaved after the carboniferous deposits were laid down because, when we examine the layers of rock as they exist to-day in the districts named, we find that the carboniferous beds lie over the Old Red Sandstone formation in layers which are almost everywhere in the same direction, as its own surface, as in Fig. A, Plate VI.

Oftenest indeed the tops of the mountains are now stripped by the weather, so that the layers as they actually exist could be shown as in Fig. B.

But, if the layers of limestone, shale, etc., had been laid down after the mountains of Old Red Sandstone had been ridged up, they would occur as horizontal deposits in the hollows between the mountains as in Fig. C.

As a matter of fact this is how both the Carboniferous and the Old Red Sandstone deposits occur as regards the Silurian rocks which had been thrust up out of the horizontal position by the old Caledonian foldings, and that is how we know that these older

foldings occurred before the period of fresh-water lakes, in which were formed the beds of Old Red Sandstone, and before the period of open sea which gave Ireland the limestone floor of her great central plain.

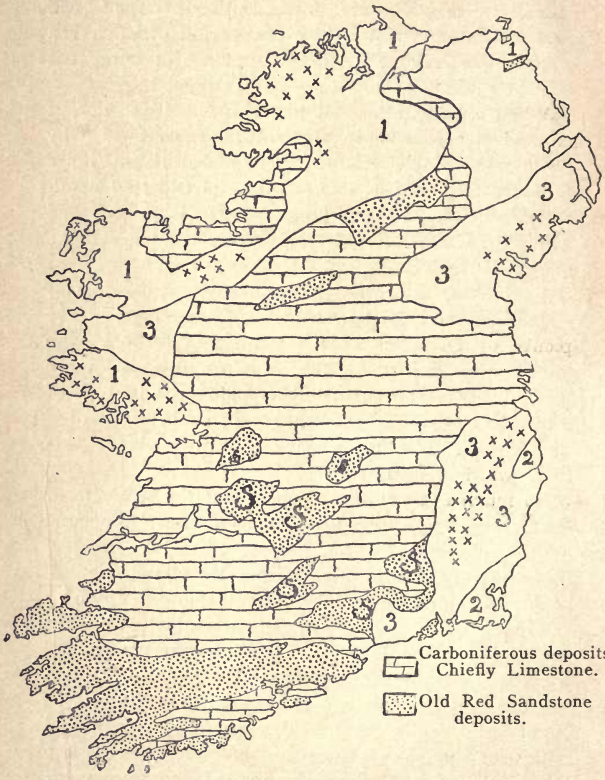
When a thing fits itself to the form of another, it is said to *conform* to that other. That is why geologists speak of the layers of limestone in Figure A, as resting *conformably* on those of Old Red Sandstone; whereas, in their language, the layers marked **a** in Fig. C rest *unconformably* over the older rocks marked B.

By looking attentively at railway cuttings, cliff edges, quarries, and even open drains, one can see plenty of examples of these things. To one who knows even a little of the story of how rocks are formed, every cliff-cutting, every stone, in fact, is of interest, carrying the mind out over the uncounted ages which have been since our little planet was flung whirling into space.

So much has yet to be said about the deposits of the Carboniferous Period that they will have to occupy another chapter. We have done well in this chapter, if we have formed an idea of how the Old Red Sandstone was laid down in lake floors unconformably over the older rocks; and of how then a gradual sinking of the land occurred, making most of the present Ireland a great sea-floor, over which the Carboniferous Limestone was deposited; and of how, at the edge of this great sea, sandstones, shales and occasional coal measures were laid down; and of how, towards the end of the period, when, the sea growing shallower, the area alternated between marshy land and shallow waters, these shales and coal measures must have

PLATE VII.

MAP OF IRELAND SHOWING ROUGHLY THE CHIEF AREAS WHERE OLD RED SANDSTONE AND CARBONIFEROUS ROCKS OCCUR.



For 1, 2, 3, see map at the end of Chapter I. The letter S shows where the summit of an Old Red Sandstone mountain has been stripped by the weather, till the underlying Silurian rock is laid bare.

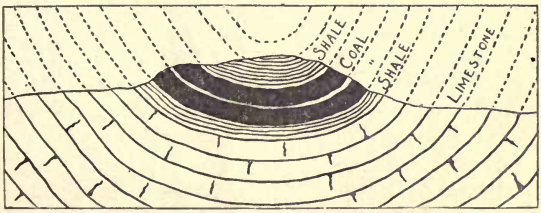
spread over most of its surface; and finally of how, during the later stages of the period, great earth movements pressing onwards from the south thrust up giant wrinkles running in an east and west direction, thus giving birth to the mountains of the South-west of Ireland; while, by the lifting of the ocean-floor, the great limestone plain of Ireland was born.

CHAPTER III.

CARBONIFEROUS LIMESTONE.

THE great mass of Carboniferous rock which covers the plains of Ireland to-day must have been originally several thousand feet thick. In Derbyshire, in Eng-

PLATE VIII.



SECTION ACROSS THE LEINSTER COAL FIELD.

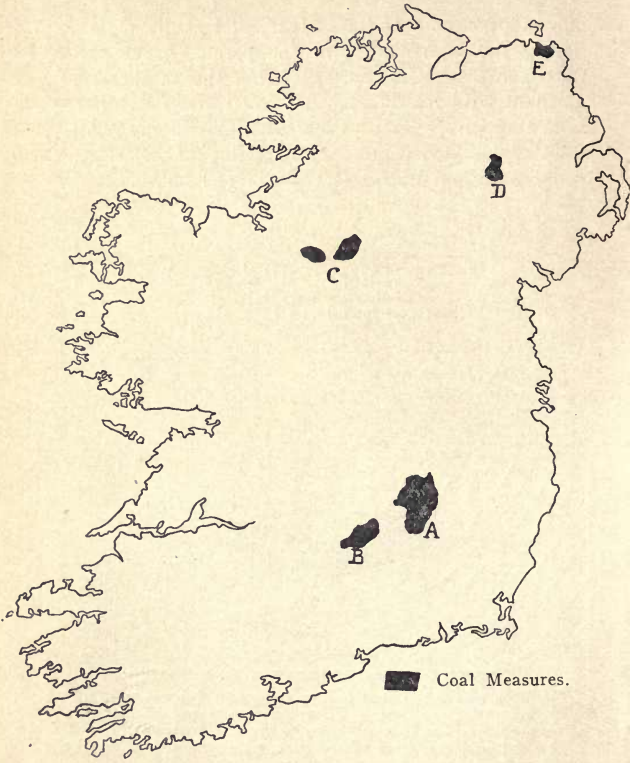
The area where the coal occurs is now a plateau relatively to the surrounding districts, but the arrangement of the strata of rock shows that it must have been once a trough.

The dotted lines show where rock, now stripped off by the weather, must have formerly existed.

land, the corresponding deposit reaches a thickness of 6,000 feet; but in Ireland, where the rocks were more exposed to the weather, their upper layers must have been worn away to a great depth. The way in

PLATE IX.

MAP OF IRELAND SHOWING ROUGHLY THE DISTRICTS WHERE WORKABLE SEAMS OF COAL REMAIN.



A, Leinster Coal-field, Kilkenny and Laoighis. B, Tipperary Coal-field, Slieve Ardagh. C, Arigna Coal-field, Lough Allen. D, Coalisland and Dungannon, Co. Tyrone. E, Ballycastle, Co. Antrim.

A and B are anthracite coal measures, and resemble those of South Wales. C and D are ordinary bituminous coal. E resembles the coal measures of Scotland.

which the Kilkenny coal-field occurs leads one to believe that coal seams must have once existed in many of the Carboniferous regions all over Ireland, but that they, with the layers of rock in which they were embedded, have been stripped off throughout the ages by the constant action of the weather. The Kilkenny coal seams lie in a district which has to some extent escaped weathering. Though the locality in which they occur is to-day a plateau standing up from the level of the surrounding country, the arrangement of the layers of rock in the district shows that the place was once a trough or hollow, with higher ground on either side, and that the areas alongside have been eaten down by the weather, and by the cutting out of valleys by the rivers running southward, till the one-time depression has come to stand out as an elevation. The figure in Plate IX. shows roughly the arrangement of the layers of rock in the area occupied by the Kilkenny and Laoighis coal-field, taking a section from west to east. The dotted lines show the portions of rock which must have been washed away from either side.

In the same way a study of the layers of rock in the area of the Tipperary coal seams, stretching north-west from Ballingarry, shows that the partial plateau in which they exist was formerly a depression, and that it only became a plateau by escaping the general weathering. Similarly, layers of shale and carboniferous sandstone still remain overlying the limestone in South-west Clare, and in West Limerick, though these, so far as is known, do not contain any coal seams worth working. In North-east Connaught, however, in the district round Lough Allen, a plateau of similar rock remains, and contains good seams of

coal. These are worked at Arigna, on the western side of the lake, but coal is also found on its eastern side, some seams occurring as high up as a thousand feet on the sides of Bencroy and of Slieveanierin.

Coal seams also occur in East Tyrone at Dungannon and Coal Island. Slight measures occur likewise at Ballycastle on the north coast of Antrim, and they, like those of Tyrone, are not on a plateau. They are found, however, to belong to the beginning of the Carboniferous Period, not, like the other coal-fields of Ireland, to the end of it. As a matter of fact, the sandstones in which the Ballycastle coal occurs must have formed on the shore of the great deep sea in which the limestone of the rest of Ireland was being laid down.

And so, everywhere over the great plain of Ireland, except in the few localities named, the weather has eaten away from the surface of the limestone-beds the layers of shale, including coal seams, which probably once over-lay them. For this too, perhaps, we have to be thankful. It is pleasanter to live in health in a land of green fields and of rich harvests than to droop and grow pale in a land besmirched with factory chimneys; and between employment in the open fields and employment in a coal mine or factory there is much to choose.

Since this process of weathering of rocks has been responsible for leaving us with so little coal, so making of us an agricultural people rather than one mainly absorbed in mechanical industries, we may well be interested in the inquiry how rocks come to be so weathered. Now sun, wind, hail, frost and, chiefly rain, all do their part in weathering, that is, "eating away" rocks. The sun heats the exposed

rock, and so it expands. When the sun is gone the rock cools; and, in the contraction caused by cooling, the rock often splits, and so the process of breaking up begins. We seldom have so blazing a sun in Ireland as to split rocks very much in this way; but in Palestine, Egypt and other warm countries, where the sun's heat is intense during the day, and where night comes on suddenly, one can hear the rocks split after sun-down.

Wind, blowing over rocks, lashes the rain and hail on to them, and the water washes out the loosened particles of rock which, carried away, make the streams muddy. Or, in dry weather the wind itself carries off and deposits elsewhere any loose particles which may remain on the rock surfaces.

Frost helps powerfully to break up rocks. It freezes the water which has remained in the splits and interstices of the rock. The water, in freezing, expands and so acts as a small wedge to rift the split further open. This process, repeated winter after winter, crumbles the rock surface away more than one would be inclined to believe, and is often responsible for the breaking off of great blocks of rock which then tumble down the side of the mountain, and lie about its base.

But it is the rain, more than any other weathering agent which has eaten away so much of the surface of the Limestone Plain of Ireland. Rain acts on rocks both physically and chemically; physically, for it washes out the loosened particles; and chemically, for it contains acid which it has collected from the atmosphere, and this acid dissolves certain kinds of rock, notably limestone. One can prove this action of acids on limestone for oneself by taking a piece of

ordinary limestone, such as is generally used in Ireland for metalling roads, and dropping on it a little strong vinegar or a little dilute acid, such as hydro-chloric acid. The drop of acid will fizz up, the moment it comes in contact with the limestone; a gas will be given off, and a small hollow will be eaten into the stone at the spot. Or, again, if a small piece of limestone be dropped into a glass containing some strong vinegar, or some dilute hydro-chloric acid, the piece of limestone will continue to cause a fizzing, and to give off bubbles until it is all dissolved away, and there only remains a little black or grey powder.

Now, rain water, in passing through the air, carries down with it, in solution, some of the carbonic acid gas contained in small quantities in the air; and when the rain-water falls on limestone rock these small traces of acid present in the water serve to dissolve the rock: therefore the rock is gradually being eaten down by the rain water, and carried away in solution. As Ireland is a country which gets a very constant rainfall, one can well understand how thousands and thousands of years of exposure have served to strip much of her old rock covering away.

Another result of this solubility of limestone in water charged with acid is that the Central Plain of Ireland has a number of shallow lakes. Looking at the physical map, we see the Shannon opening out into many great lakes. We also notice that much of the area of the counties Longford, Fermanagh and Westmeath is covered by lakes. These have all been eaten out of the limestone floor of the country by water charged with acids. Bogs are plentiful in Ireland; and water coming from bogs is rich in acids collected from the decaying vegetation, of which the

bogs are composed. So, when a river coming from boggy regions meets with limestone along its course, it gradually eats the limestone away, and cuts for itself a lake basin out of the limestone floor.

Sometimes a river widens out cracks in the limestone of its bed, and eats its way down through these, eventually hollowing out tunnels which deepen downward as solution goes on. Thus in time the river will have cut out for itself an underground passage, which will eventually become a great cave, like those at Mitchelstown, in County Tipperary: or, perhaps, the overlying rocks will give way, and so a lake will be formed, as happened at Lough Corrib, which an underground river still connects with Lough Mask.

Limestone is used for many purposes. It is burned for making lime, and lime is much used on farms, for improving the soil. Lime, added to the soil, sweetens and opens it up, and causes the farm manures, and even artificial manures to act more effectively. Sometimes limestone itself, ground down to a powder, is used as a soil improver, it being milder than lime, and less liable to cause damage if applied too freely. In reclaiming bog land, both powdered limestone and lime are equally of service. We may, therefore, say that limestone indirectly helps our food supply.*

Limestone is used for metalling roads almost everywhere in Ireland. The fact that it is soluble in rainwater renders indeed not an ideal stone for roads. However, it has the two-fold advantage—that it is plentiful and easily broken.

* The question of the Liming of Land has been treated exhaustively by Mr. Joseph Hanly, D.Sc., F.R.C.Sc., in his book, *Mixed Farming,* to which readers, interested in the subject are referred.

But the most important use of limestone is its use for building purposes. It is a very suitable stone for building with, for it can be easily cut to the required shape. Moreover, when quarried, it breaks off in fairly regular layers, not like granite, for instance, which breaks rather in angular fragments. Limestone looks well in a building, and even the modern red brick building is greatly improved in appearance when it is given corner stones of good grey limestone.

The interior of buildings, chiefly of churches and public buildings, is often ornamented with pillars and tablets of a transformed limestone—namely, marble. For marble is limestone or chalk rock, which, in the course of the great earth changes, has been subjected to great heat and pressure. Marble is plentiful in Ireland, just as limestone is. It is red, grey, black, etc., in colour, according to the particular colouring matter prevalent in the district where it exists. Thus, in County Cork, where an oxide of iron has tinged all the rocks red, Midleton red marble is quarried. In Kilkenny the marble is black, owing to the presence of a small quantity of carbon. In other areas, where the limestone was fairly pure, a streaky white marble is found. Of the dazzling white marble of Rathlin we shall have more to say in another chapter.

In Connemara a very hard, semi-transparent, dark green stone is quarried, which is popularly known as Connemara marble. This stone takes a very beautiful polish, and is so much prized that it is often made up and set into gold brooches and other ornaments. It is what is called serpentinous marble, and differs in many respects from ordinary marble. It breaks with an almost clean fracture, and is affected only by strong acids; whereas ordinary marble, which is only

transformed limestone, breaks with a rugged fracture and fizzes up under dilute acid, just as limestone does.

There is, however, also quarried in Connemara a green rock of much lighter green colour than the serpentine. It breaks with a rough fracture like other kinds of marble, and like them it is affected by dilute acids. This is really marble. It is made up into ornamental pillars, etc., like the other kinds of marble. But it is the darker green stone, the serpentine, which is the much-prized stone, known generally as "Connamara Marble."

So, to the great long geological period known as the Carboniferous Period we owe such coal measures as we have, our abundant supply of limestone, and our many and beautiful varieties of marble; at least the material of all these was laid down during that period, and the transformation of the forest débris into coal, and of the limestone into marble may have gone on into much later periods. During that period, too, there must have been repeated volcanic activity in the area now covered by East Limerick and West Tipperary. Isolated ridges and groups of hills now stand up from the general level of the limestone plain there. These are all formed of volcanic rock. They are clearly the lavas of an old volcano which must have been active beneath the carboniferous sea somewhere in that region, for carboniferous rocks underlie them, and on their sides strata of carboniferous rock still remain overlying them in spite of all the long intervening ages of exposure to the weather.

The plant life of the Carboniferous Period closely resembles that of the later Old Red Sandstone, consisting, like it, almost entirely of flowerless plants;

PLATE X.—SPECIMENS OF FAUNA AND FLORA OF THE CARBONIFEROUS PERIOD.

Fig. 9.

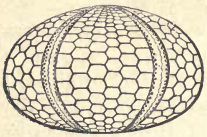
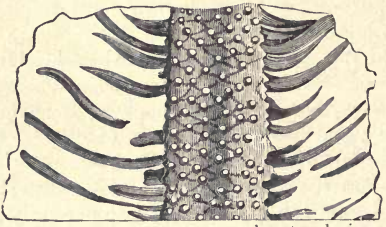


Fig. 10.

Fig. 11.



¼ natural size.

Fig. 12.

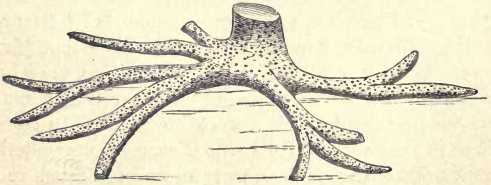


Fig. 9. } Fossils from Irish Carboniferous Limestone (re-
Fig. 10. } duced.

Fig. 11.—Tree stem from Carboniferous Deposits.

Fig. 12.—Root of tree from Carboniferous Deposits.

ferns, horse-tails and club mosses. Many kinds of fern, which then abounded, have representatives among the flora of to-day, but many others have died out; while the present representatives of the club-mosses and horse-tails are mere dwarfs in comparison with those of the Carboniferous Period. Our present club moss, for instance, is a low creeping plant: that of the Carboniferous Period was a great tree, sometimes upwards of fifty feet in height.

All these plants grew in low marshy places; but in the higher and drier regions pine trees must have flourished; for, embedded in the sandstones of the period we come across fossilised trunks of these in lying positions, as trees would be, which were washed down by a flood after a big storm had uprooted them.

A plant, whose fossil remains are very plentiful in the coal-bearing strata, is the Sigillaria.

It gets its name from the seal-like impressions on its stem, the Latin word for "seal" being *signum*, which has a diminutive form *sigilla*. Each little impress is really a scar where a leaf fell off. The Sigillaria must have been a dweller in the marshy regions, for it is found, stem and roots, in the position in which they grew, in the clays underlying the coal seams. When full grown it seems to have reached a height of fifty feet. The plant is of interest, as it seems to have no near representative among the flora of the world to-day; so that, although we are able to note a fairly continuous progression of life on the earth, we shall find that certain forms dwarf and die out, while others go on developing, and giving rise to new and more complex forms.

The traces of animal life found fossil in the carboniferous strata show a development on that of the

previous times. The back bones of larger fish are found, the teeth of sharks are plentiful in the lagoon remains (showing that the sharks must have occasionally penetrated in from the outer deep); also remains of amphibious animals are found. Insects, too, appear, but birds not yet. The animal life of which the most

PLATE XI.—TREE FERNS IN THE WORLD TO-DAY.

Fig. 13. Fig. 14. Fig. 15.

Fig. 13.—Tree Fern from Isle of Bourbon (Indian Ocean).
Fig. 14.—Tree Fern from Mauritius (Indian Ocean).
Fig. 15.—Tree Fern from Brazil.

The Tree Ferns in the world to-day are but dwarfed representatives of those of the days when coal was being laid down.

abundant traces remain from this period is, of course, the coral and shell-fish type. Infinite numbers of these built up the great masses of limestone which cover so much of the earth to-day, and of which, as we have seen, Ireland has an abundant share.

CHAPTER IV.

THE ANTRIM AND DERRY PLATEAU.—I.

LOOKING at the map, Plate VII., we see the rock foundation of all the Irish area marked, except that of a small portion in the North-east, covering chiefly the counties of Antrim and Derry.

PLATE XII.—ROCKS OVERLYING THE CARBONIFEROUS LIMESTONE IN ANTRIM AND DERRY.

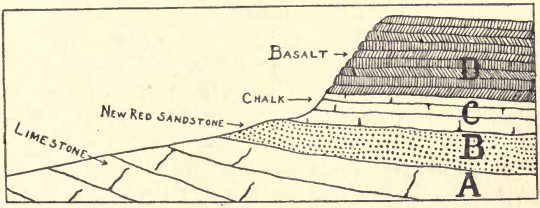


Diagram showing roughly the arrangement of the rock strata at the edge of the Antrim and Derry plateau.

The carboniferous rocks no longer appear nearest the surface here; not that they have been all weathered away, as they have from the tops of the Slieve Bloom and the Galtees, but that, in the long ages since the floor of the carboniferous sea was first raised into dry land, they have been covered by newer deposits. From where the limestone ceases to appear near the surface in East Tyrone and Derry it is found to be continued beneath the other rocks which form the plateau to the east. This plateau is covered with a hard black rock quite different from most of the rocks

found elsewhere in Ireland. Approaching the edge of this plateau, say from Limavady, and studying the lie of the different strata of rock as we travel eastward, we find the carboniferous rocks dipping beneath the other layers of rock somewhat, as shown in Plate XII.

Now it is evident that the layers of rock marked B, C and D must have been laid down later than those marked A. Let us examine those layers in turn. Layer B consists of a Red Sandstone much less dark and less compact than the Old Red Sandstone which we have met in the South of Ireland; layer C consists of chalk rock, or white limestone, as it is called; and layer D consists of a hard black volcanic rock known as Basalt. If we cross the plateau to the Antrim coast, we find the same arrangement of rocks repeated along the cliffs from Garron Point to Belfast—dark, frowning Basalt, overlying gleaming white chalk, which in turn overlies bright coloured sandstone. Along the cliffs at intervals, one can see perpendicular masses of the Basalt passing up through the other rocks. This points to the origin of the Basalt, which must have poured up in a molten state from beneath, and flowed out over the other rocks, till it had spread a thick covering of itself all over the plateau.

Geologists, by studying these rocks and the corresponding rocks in other parts of the world, are able to tell us how it must have been with our part of the world during the long ages which it took for these rocks to accumulate; and, by a study of the fossils found in them, they are able to piece up for us, in some sort, the history of the development of plant and animal life during all that length of time. The result of their studies is a tale of wonderful

interest, and it will unfold itself to us, as we study the rocks in what is, geologically speaking, the youngest portion of our land.

Firstly, then, whenever at a river-gorge or railway cutting in this district, the junction of the carboniferous rocks with the overlying strata can be examined, it is noticed that the overlying rock must not have been laid down immediately upon the Carboniferous deposits; for these latter show signs of having been subjected to a long period of weathering before the other rocks were laid upon them. In fact there is a great gap in the continuity of the rocks here, and to fill up the history a study must be made of the corresponding rocks elsewhere.

If we trace the carboniferous deposits across Europe, we find that in many cases they were covered by other rocks before the weather could eat them down, that is to say, before they were raised into dry land. Of these rocks, which lie conformably over the Carboniferous system, a great thickness occurs in the province of Perm in East Russia. The rocks are therefore called **Permian.** They spread over much of the present European continent and of central Britain. Small patches of them occur even in North-east Ireland, at Holywood, on the south shore of Belfast Lough, and near Stewartstown in East Tyrone. These rocks consist very largely of a bright red sandstone. They seem to be mostly the deposits of great lakes or of inland seas. From their distribution over Central Europe, and from the almost complete absence of them in Ireland, we must conclude that during the lengthy period when they were being laid down (for the deposits are of great thickness in many places) great sea-inlets, or inland seas, must

have spread over the European and English area, while Ireland must have remained dry land, and, with Highland Scotland and Wales, still formed part of the ancient continent extending away north and west towards Norway and Greenland. Into this continent, at some part of the Permian period, a narrow creek of some of those inland seas probably penetrated from the east, and laid down the small Permian deposits in North-east Ireland.

It is worth while to remember the name "Permian" given to this first of the post-Carboniferous Periods, for the Permian strata close the geological era when only the oldest forms of life existed on the earth. In none of the rocks laid down up to the end of the Permian deposits do any traces of mammals appear, nor of birds; and the plant-life, though luxuriant, consisted mostly of flowerless plants, such as ferns and mosses. For this reason, scientists have agreed to classify all the rocks laid down up to the end of the Permian Period under the one general name, **Palæo-Zoic,** a name derived from two Greek words *palæos*, meaning "ancient," and *zoe*, meaning "life." Palæozoic rocks, therefore, include Pre-Cambrian, Cambrian, Silurian, Old Red Sandstone, Carboniferous and Permian; and most of the rocks of Ireland were laid down before the Permian time. So, when we speak of Ireland as an ancient country, we speak a deeper truth than the historian dreams of.

While Ireland was still part of a great continent lying to the north-west, what is called the **Mesozoic Era,** or Era of Middle Life crept in. The north-east corner of the present Ireland, with its then continental climate, seems to have become a sandy waste, with occasional salt lakes, like the steppes of South-eastern

Russia, or like the desert plateau of Utah to-day. We know this because there exist, near the surface, in the depression around Lough Neagh, beds of a peculiar sandstone in whose folds occur deposits of gypsum and rock-salt. These deposits tell their own story, for they must have been encrusted, during periods of evaporation, round the edges and on the floors of salt lakes, just as is happening to-day, everywhere that salt lakes occur. The district around the present Carrickfergus remained a salt lake for so long a time that quite thick beds of salt were deposited there, one of them actually eighty feet in thickness. These salt deposits were discovered accidentally in the year 1853, when a boring was being made at Carrickfergus in the hope of finding there a continuation of the Tyrone Coal-field under the Antrim Plateau. The expected coal-measures were not found, but the discovery of the beds of rock-salt and gypsum more than repaid the search.

The sandy wastes and salt lakes, of which evidence is preserved in these newer sandstones round the edge of the Antrim plateau, must have extended far south of Belfast Lough, for there still remain, in a small area away down near Kingscourt, deposits of a similar sandstone with layers of gypsum. This shows that a salt lake must have existed in that place, for gypsum is one of the first solids which are deposited when a salt lake suffers much evaporation.

The **New Red Sandstone** and salt deposits of Cheshire and of Central Europe were laid down during the same period in similar sandy wastes and saline lakes. Because in Germany, where this system of rocks is very well represented it falls naturally into three divisions, the whole system has come to be

known as **Triassic,** from the Greek word *Trias*, meaning "three."

It is in the Triassic strata that the first traces of mammalian life have been found. Fossil teeth and jaw bones have been discovered in the later strata of the Period, and zo-ologists, bringing the light of their science to bear on these, classify them as belonging to a mammalian animal of the lowest form, a type of animal which has now died out in the Northern Hemisphere, but which is still represented in Australia by the "porcupine ant-eater," Echidna.

The New Red Sandstone strata which appear round the edge of the Antrim and Derry plateau to-day belong to this period. They are, therefore, spoken of as Triassic Sandstones; and when we walk over them, or come across sections of them at river or railway cuttings, our mind can travel back over the untold ages to a time when this area was a great desert, sandy waste, with occasional salt lakes; a time when the luxuriant plant life, which formed the coal measures, had dwindled away before such forbidding and arid conditions.

Over the Triassic deposits round the edge of the Antrim and Derry plateau, but in most cases showing, as before, a big gap in the history of their laying down, come great layers of an almost white limestone, generally called "Chalk." In a few places, however, as, for instance, along the coast from Glenarm to Larne, thin layers of dark blue mud-stone or compressed clay separate the Chalk from the New Red Sandstone deposits. These thin layers, insignificant as they might seem, give the key to a whole wonder-tale in the history of life upon our globe. Traced across England to the continent of Europe,

they prove to be part of a system of rocks which is particularly well seen on the flanks of the Jura mountains. The whole system is, therefore, called **Jurassic,** and the tale which the study of it tells is this:—

Towards the end of the Triassic Period, much of what was an immense arid continent began again to sink beneath the sea. First, great sea-inlets were formed, and eventually the sea flowed in freely over the site of the present Europe; the Irish area remained as dry land on the north-western margin of this sea. But the sea-edge must, at some part of the Period, have just penetrated to the Antrim and Derry area, leaving, as its legacy, the mud deposits which, now compressed, form the dark blue clay noticeable here and there in thin bands underlying the chalk around the rim of the present plateau. That sea, whose edge just penetrated to our area, must have spread over all the region which now forms South-east England. It covered, as we have seen, much of the site of the present continent of Europe. On its floor were deposited, as on the floor of the older sea in carboniferous times, layers of limestone, shale, or sandstone, according as the locality in case was open sea or nearer a coast. This time, however, these different kinds of rock frequently alternate with one another, which leads us to believe that there must have been many fluctuations in the area occupied by the sea. The sea floor deposits laid down during this period can easily be distinguished from those of earlier times by the more developed types of marine life found fossil in them. Moreover, being very much less ancient, and therefore much less compressed than the deposits of the Carboniferous Period, they are

much more easily quarried and cut to any required shape. For this reason the name *free-stone* is often applied to them. Portland freestone, for instance, belongs to the deposits laid down in Dorsetshire in England during the Jurassic Period. Such stone is absent in Ireland; therefore, it must have been only the sea-edge that penetrates to our area. Limestone is a deep-sea deposit, but clay, such as we have from the Jurassic Period owes its origin to mud, such as would be laid down near a coast, or at a river mouth.

The Jurassic Period must have extended over an immense length of time to admit of the great thickness of rocks being laid down which the system includes on the continent of Europe. The period is chiefly remarkable for the enormous development of reptiles which took place within it. At Colin Glen, near Belfast, in one of the layers of clay, which we have already noted as the thin Irish representative of this period, fossil bones and teeth of a great swimming reptile have been found. In the Jurassic strata elsewhere there have been found complete fossils of monster sea-lizards, and of other great lizard-like animals with necks twenty feet long.

Fossil remains are also found of flying reptiles—bat-like creatures having heads with long jaws carrying sharply-pointed teeth. Bird-like animals appear, and even true birds at the end of the Period, but different from the birds of to-day in that they were toothed; and some mammalian remains occur, though not in the Irish area.

But the Jurassic Period has well been called " The Age of Reptiles "; and it is very interesting that, even in the thin Irish representative of it, we should

find fossil reminders of those huge reptiles which once inhabited the earth, and of which the present alligator and crocodile are merely dwarfed representatives.

Next comes the period which gave to Ireland the Chalk or White Limestone of Antrim and Derry; but that will have to occupy us in another chapter. A glance at the tabular statements of the older and middle geological eras, which appear at the end of the book, will, however, serve to sum up provisionally here the work which we have done in this and previous chapters.

Chapter V.

THE ANTRIM AND DERRY PLATEAU.—II.

We have now reached the story of the famous Antrim "white-limestone" which, as we have seen, peers out all round the edge of the hard black basaltic covering of the Antrim plateau. This white limestone is found to be part of an extensive system of rocks which over-lie the Jurassic strata in most parts of the present land of Europe (and in much of the present land of the world, for that matter) and which spread out far beyond the edges of these strata, in thick beds of a soft white rock called **chalk.** That this rock is ocean floor deposit there can be little doubt. Seen under the microscope it is found to contain in abundance the remains of tiny organisms, such as are dredged up from the ocean floor in the deep-sea soundings to-day. Similar deposits of white rock appear in India, Persia, Asia Minor, and in most of southern and central Europe, except for a ridge run-

ning eastward from Brittany and through the Black Forest Mountains to Bohemia; and it is probable that they once covered this ridge all across France, though they are now worn away. They form the chalk cliffs of Dover, cover much of South-east England, and even extend beyond North-east Ireland to the islands of Western Scotland. This means that a great sea must have covered these areas for a considerable length of time. That sea must have extended over North-east Ireland, at least over the site of the present Antrim and Derry, probably over much more. The deposits, which accumulated on the floor of that sea, form the chalk rock which is so common in the Northern Hemisphere to-day, from the distant Rockies to our own Antrim, and from the cliffs of Dover to Hindustan. It is called a **cretaceous** deposit, from the Latin word *creta*, which means "chalk." The word indeed came into Latin from the name of Crete Island, where this rock is common. The Period during which the Chalk was laid down is spoken of as the **Cretaceous Period;** and the ancient sea in which it was laid down is spoken of as the *Cretaceous Sea.* It is interesting to reflect that where now stand the storied mountains of Slieve Mish and Sinai, there once rolled the deep Cretaceous Sea.

A study of the fossil remains of the Cretaceous Period shows that the enormous reptiles remained right up to the end of the Period in great vigour, while other forms of life developed and multiplied. There is a great development traceable in the shell-fish of the Period; but the most remarkable progression of life appears in the vegetable kingdom. In the later deposits of the Period flowering plants appear in great abundance, and trees and grasses, very like

our common trees and grasses of to-day, are met with.

While the Chalk Sea still covered much of Europe, the submerged north-east corner of Ireland gradually tilted up again into dry land. Then the weather began to act on it, eating down the chalk which it carried away in solution, and leaving behind, strewn over the surface, the flinty pebbles which were contained in it. The surface is now covered with thick layers of hard basaltic rock. But the story of the coming of the basalt belongs to the next era, or the Era of Recent Life. Before passing on to the study of it we will do well to sum up again here the tale of the Mesozoic Era, represented by the rocks underlying and bordering this basalt-covered plateau.

We have seen that the rock-foundation of all of the present Ireland, except for the small North-east corner, dates from before the Permian Period, that is to say, was laid down before the end of the Palæozoic Era, or the Era when only the most ancient forms of life existed on the earth. The small north-east corner has representatives of all three Periods which make up the Mesozoic Era. Deepest down are the Triassic Sandstones with their deposits of gypsum and rock-salt, telling of a time when desert sandy wastes covered the area, when plant life dwindled, but when what seems to be the first mammal remains appear. Then come the Jurassic clays, commonly called **Lias.** The origin of the word is uncertain. The workers in Somersetshire, in England, where these deposits occur abundantly, called them *lyers*, which would be their way of pronouncing *layers*; but, perhaps, without knowing it, they were using the old Celtic word *Lia*, meaning "flag" (Armorican *liach*;

Irish *leac* or *liag*). However, that may be, the word *Lias* is now commonly used to describe these clays; and the fossils found in the Jurassic deposits tell of a time when monster reptiles crawled on the earth, flew in the air, waded in the rivers and swam in the seas—a period when, while Ireland remained land, a great sea, now shrinking, now growing large, spread over the present Europe, and at some part of the time sent up a shallow inlet in which was deposited the blue clay intercalated with Limestones here. Finally come the chalk deposits, telling of a time when the North-east corner so sank as to admit a clear-water sea, which, spreading over much of the present Europe and across Asia Minor even to India, must have washed, from the east, against the stout old hills of Donegal. And during the long, long period before that sea shrank back, plant life had progressed enormously on the places that remained land, so that the fossil remains towards the end of the period show that parts of trees and grasses almost like our present trees and grasses were washed down from the land. In the animal kingdom the advance in the types of shell fish is very marked; mammal remains occur (though not in the Irish area), but they show little development on the mammalian remains occurring in the two previous Periods.

The end of the Chalk deposits closes the Era of Middle Life, or Mesozoic Era, as it is called. During the next Era mammal remains continue to occur, at first in small numbers, then in greater abundance, and showing a closer resemblance to our present types, until, towards the end of the Era, we come to the fossil remains of animals almost all of which are like those that exist on the earth to-day. Finally,

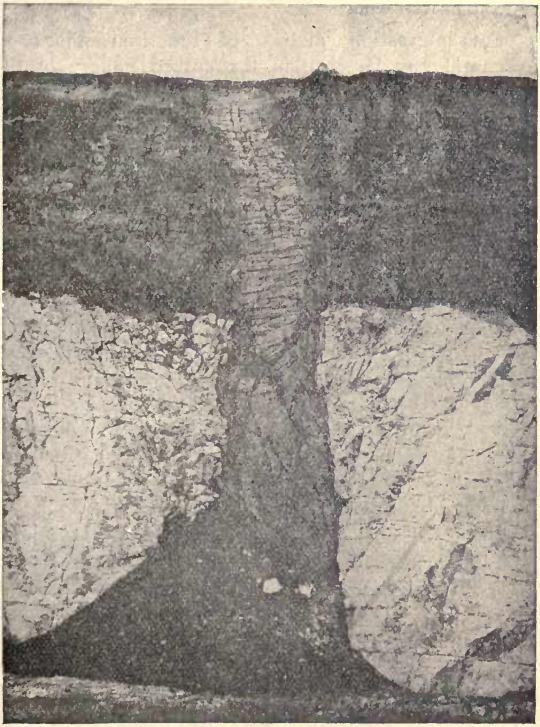
man himself makes his appearance, to whom alone, of all the countless forms of life which have appeared on our planet since the first tiny living cells inhabited the Cambrian seas, it is given to study something of the great and wonderful changes which have passed over the face of the world in which he lives. The Era during which all this wonderful development of mammalian life took place is called the Era of Recent Life, or, to use the scientific word, the **Cainozoic Era** (the Greek word *Kainos* means "recent"; and *zoe*, as we have already seen, means "life.") The Cainozoic Era really extends right down to our time, though it is usual now to classify as a fourth or Human Era the time since traces of the presence of man began to be embedded in the strata. The Cainozoic Era is the Era during which the soft rocks and clays overlying the Chalk deposits in South-east England and elsewhere were laid down. The Irish area, however, remained land during this whole Era, and so we have in Ireland no Cainozoic sea-floor deposits worth mention to study. But, all the same, this Era was a very interesting one for our country. The recently deposited Chalk rock of the close of the previous Era might easily have all been weathered away ere now, were it not that, early in the Cainozoic Era, there came about, in the Antrim region, great volcanic disturbances, which resulted in giving to the chalk a hard, thick protective covering of basalt. These disturbances split the chalk in long fissures running in a north-west and south-east direction; and out through these fissures there poured from beneath the earth-crust floods of molten rock, which spread themselves all over the surface. When this molten rock

cooled, it formed the hard black rock, called **basalt,** which covers the plateau of Antrim and East Derry to-day.

Once the flow ceased for a considerable time; and during this long period of rest the weather acted on the exposed surface of the basalt, decomposing it and forming from it clays rich in iron and aluminium ores, even as such clays are being formed over the basaltic rock surfaces in the Deccan plateau, and in other tropical regions to-day. Also the water after the rains carried down with it in solution some of the iron in which basalt is so rich, and deposited it as an oxide on the floors of the lakes which formed in the hollows.

When the volcanic activity recommenced new outflows of basalt spread themselves in layers over the older ones; but the interval of rest is marked by a layer of decomposed basalt which appears as a zone of reddish material right round the edge of the plateau between the upper and lower basalt. It can been seen as a red band half way up the cliff overlooking the Giants' Causeway. This red zone of decomposed basalt contains workable seams of iron ore at Glenariff, at Glebe, near Glenarm, and other places. In the upper portions of the zone the iron ore is often missing, and is replaced by a greyish-white clay, **bauxite.** Bauxite is of value as a source of aluminium, a very light untarnishable whitish metal, which has come to be greatly in demand of recent years. The clay got its name from a village called Les Baux, in southern France, near the mouth of the Rhone, where good deposits of it occur, and have long been worked for the aluminium which they contain. In Antrim bauxite occurs at Ballintoy, and also west and south of Glenarm higher up than the iron deposits.

PLATE XIII.—BASALT OVERLYING CHALK.



The photograph was taken at Cave Hill, Belfast. Notice what looks like a black column going through the Chalk and Basalt alike; it is the dyke through which the molten basalt flowed out.

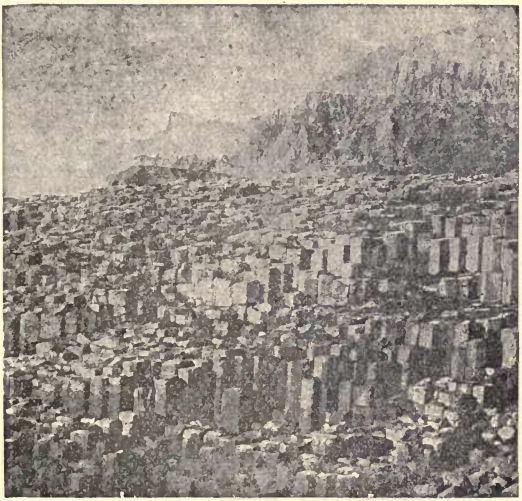
Often one clay merges gradually into another, the upper layers being richer in aluminium ore, and the lower in iron ore.*

An interesting picture of the iron mines at Glenariff can be seen in the curved gallery of the National Museum, Dublin. There also can be seen specimens of all the chief rocks which occur in Ireland, and one can learn more about rocks and their secrets from a few visits to the Museum collection than from many days spent over books. Some basaltic prisms from the Giants' Causeway itself are to be seen there, and they remind us of a very interesting feature of the Antrim coast. For sometimes, when the molten basalt shrank in cooling it formed itself into long upright hexagonal prisms. A mass of such prisms on the north coast forms the Giants' Causeway, which is one of the great natural curiosities of Ireland. The old story-tellers, who loved to weave a tale round every hill and stone and stream in their native land, used to tell that Fionn Mac Cumhaill (who, in the Ulster stories, is always a giant) was making himself stepping-stones from there to Scotland, and died before he had completed his task; and that his brother giant, Fionn Gall from Scotland was building a causeway from there to meet the Irish Fionn. As a matter of fact, the story, like most of its sort, contains a half-truth. The giants in case were the giant forces of the earth sending out its flows of molten rock; and if we draw a line on the map or on the globe, from Antrim through Islay and

* The student interested in the subject will find analyses of the composition of the different clays in the interbasaltic zone neatly tabulated in the *Geological Survey Memoir on the Interbasaltic Rocks of North-east Ireland.*

Mull to Skye and to the Faroë Islands, we shall be passing over a region whose rocks, like the Giants' Causeway, are formed of basalt. At Fionn Gall's

PLATE XIV.



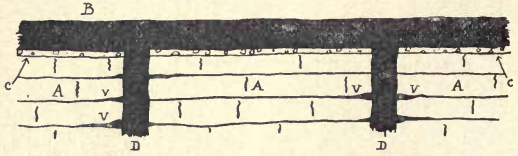
THE GIANTS' CAUSEWAY.

Cave, in Staffa Island, the basalt in cooling formed regular hexagonal prisms like those of the Giants' Causeway.

But let us return to the outflows of basalt over Antrim. It is natural to expect that all this molten and immensely heated matter, pushing its way out with such enormous force, would alter the rocks with

which it came in contact, just as we have seen that granite altered the rocks through which it sought to force itself upwards. So in reality the basalt has altered the rocks through which it rent itself fissures, and over which it lies. It has hardened and compressed the soft chalk rock until, in places, it is almost as hard and as compact as the basalt itself. Sometimes, too, it has transformed whole masses of the chalk

PLATE XV.—DIAGRAM TO ILLUSTRATE THE OCCURENCE OF WHITE MARBLE AT RATHLIN ISLAND, CO. ANTRIM.



A,A, Layers of chalk altered to White Marble. B, Basalt which flowed out as molten rock through the dykes D,D, sometimes intruding itself horizontally in veins V,V, through planes of weakness in the chalk. C, Deposit of flints left from the weathering down of the surface of the chalk before the basalt poured out. The basalt flowing over them, in its hot molten condition, baked them red. D,D, Dykes of basalt. V,V, Veins of basalt.

into beautiful white marble. An excellent example of this transformation can be seen at Rathlin Island—the Rathlin of Bruce fame. Black dykes of basalt run up through the rock; and between them, where the heat and pressure must have been immense, what was once a chalk deposit has been converted into beautiful white marble. (See diagram.)

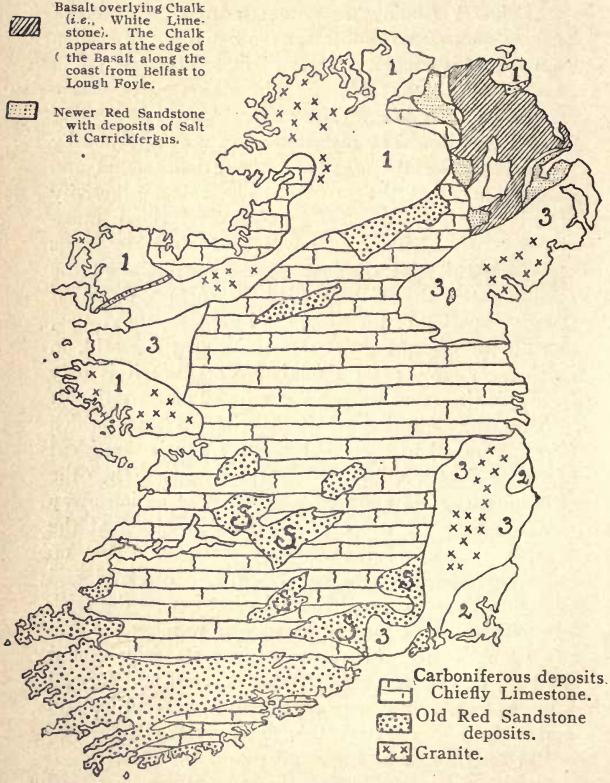
While over the Antrim region these basaltic flows were succeeding each other, disturbances from within the earth were also going on in County Down. Eastward of Newry (where the old granite range terminat-

ing in Slieve Croob already existed since the date of the Leinster Chain) there was a new invasion of igneous rock. Great subterranean cauldrons of molten rock forced themselves upward in this district, and formed the present Mourne Mountains, with Slieve Donard as their king. The molten matter in cooling formed granite. The mountains are now stripped by the ages of weathering, and the granite, cold and hard, appears at the surface. The volcanic activity of this time extended far inland over Ireland; occasional traces of it are met with as far west even as Galway. This was the last great disturbance of the earth-crust in the Irish area. It is worth noting that the up-thrusting of the Alps, the Pyrenées, the Andes, and all the present great mountains of the world, in fact, dates from after this time, and that it is only from this time that Europe has existed as a continent.

After the disturbances in Antrim, the land which joined Donegal to the great North Atlantic Continent of the ancient world must have given way. Then the Atlantic flowed in and began its work of eating away at the coasts. Later on, a slight depression at the south-east allowed the Atlantic waters to flow up between Ireland on the one hand, and England and Wales on the other, and formed what is now the Irish Sea. This in time pushed its way up to meet the arm of the Atlantic which was eating its way round Rathlin; and so, eventually, was severed and formed into a completely sea-engirdled land—our island home—Ireland sea-begotten, fire-begotten!

Plate XVI.

Map of Ireland Showing in Broad Outline the Whole Geological Formation.


Basalt overlying Chalk (i.e., White Limestone). The Chalk appears at the edge of the Basalt along the coast from Belfast to Lough Foyle.
Newer Red Sandstone with deposits of Salt at Carrickfergus.
1
2
3
S
Carboniferous deposits. Chiefly Limestone.
Old Red Sandstone deposits.
Granite.

1. Pre Cambrian Rocks; 2, Cambrian Rocks; 3, Silurian Rocks. The letter S shows where the O.R.S. is so eaten down by the weather, that the Silurian Rock beneath it is laid bare.

Chapter VI.

THE COMING OF THE ICE AGE—BOULDER CLAY AND LATER DEPOSITS.

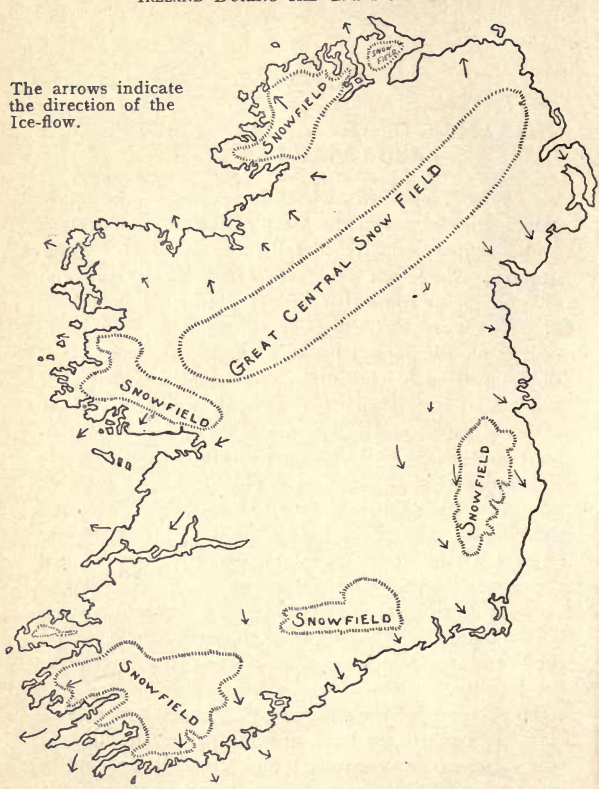
We now come to what is perhaps the most wonderful chapter in the story of the Birth of Ireland —the chapter which will tell us how the rock foundations, which we saw completed in the previous chapter, came to be covered over with such deep beds of rich clay. For, all over the country, except of course on the high mountain ridges, there exists a thick covering of clay often intermingled with coarse gravel. It is this rich clay deposit which, combined with our moist and temperate climate, has made our land so pre-eminently an agricultural country.

Though some of this clay is obviously river deposit, laid down at flood times when rivers have overflowed their banks, the great bulk of it is clearly not river deposit at all; for it does not occur in strata, and the stones intermingled in it are not rounded as stones brought down by rivers would be. Neither is it formed by the mere crumbling away of the rock-floor beneath; for the stones which occur in it are often foreign to the locality.

To account for the presence of this thick mantle of clay, we have to go back in imagination to a period when Ireland was covered and crushed beneath a giant mass of ice—grim, frowning, pitiless ice—that held the land for ages in its grip, freezing out all except Arctic forms of life, or driving them south before it as it advanced. There the solid ice lay, piled

Plate XVII.

Ireland During the Great Ice Age.



During the Great Ice Age a vast Snow-field covered Ireland to a depth of over a thousand feet. The snow lay highest in the district between Fermanagh and Lough Neagh, and the ice pressed itself out from there, in all directions, to the sea.

It is to the Great Ice Age that Ireland owes her thick covering of Boulder Clay and her eskers or gravel ridges.

up over the land to a height of over a thousand feet, ever melting where it pressed against the ground beneath, ever gaining more ice from the snow-falls on the surface, ever creeping imperceptibly outwards, and all the time making of our land a vast waste of ice, something like what Greenland is to-day. This all came to pass during the **Great Ice Age,** which, geologists tell us, must have set in towards the close of the Cainozoic Era, and probably before Ireland was yet quite severed from the European continent.

For some reason a period of great cold appears to have set in gradually all over the world, but especially in the Northern Hemisphere, and the cold went on increasing until a large part of Europe, and of North America, became like the Arctic regions of to-day. The rains gave way to snow, and in our area the snow was so heavy that in time it piled itself up more than a thousand feet in thickness, filling up all the valleys and the whole of the Central Plain, and spreading itself like an enormous cap over the entire country. The accumulated snow was constantly pressed down by more snow which fell on its surface, till the underlying portions became compacted into a solid mass of ice which pushed itself outward gradually, even as the Greenland ice-field does to-day, seeking the easiest slopes out to the sea, where it broke off and floated away as ice-bergs. The snow seems to have piled up highest in the district between Fermanagh and Lough Neagh; and so the ice kept pressing its way outward from there in all directions, while, in the meantime, fresh falls of snow re-enforced the ice-fields, and made up for what was being carried off in the form of ice-bergs from the edges, and in the form of water from beneath the ice-cap.

So great was the thickness of the ice-cap in proportion to the ordinary hill chains of the country, that, where the hills lay in its passage, the ice moved onwards and upwards over their sides and summits, while the rock fragments embedded in it scored and smoothed them as it ground past, leaving them beautifully rounded, when at last the ice melted away. The ice, pressing outward from the central snow field, must have been met in the North-east by a corresponding flow of ice coming down from the great high snowfields which covered Scotland at that period. Westward the ice probably ended abruptly with steep ice cliffs where it met the ocean. From beyond Cape Clear to the coast of Norway there must have been at this time a continuous wall of ice. Southward of Cape Clear, Irish land, which is now lost to us beneath the sea, must have extended away in the direction of Spain; and it may be that in that direction the ice-fields ended off gradually in turbid streams, as they extended into warmer regions.

It is only what one would expect that for a long time all this thick covering of clay and loose stones which lies over Ireland and much of northern Europe was regarded as mere rubble deposited at various epochs by floods. However, about a hundred years ago, some Swiss scientists* set about making a serious study of the glaciers in their native Switzerland,

* The whole story of the work of the pioneers in the study of glaciation is told by Professor Grenville A. J. Cole, in his book, *The Changeful Earth* (Macmillan & Co.). Professor Cole tells how a simple chamois hunter in Switzerland was the first to suggest to one of the scientists the probable former extension of the glacier down his native valley, how the scientist at first thought the suggestion not "worth the trouble of serious consideration," but, in a few years, became convinced that the chamois hunter was right.

where the ice shrinks back every summer, leaving exposed the rock floor and sides of the valleys which it occupies in winter. They came to conceive the idea that the Swiss snow-field must have once extended outwards over southern Europe far beyond its present limits, and that the present glaciers were but the dwarfed remains of much larger glaciers which once filled the great valleys that extend outward from Switzerland.

Interest in the whole subject became very keen. Scientists in other countries followed up the evidence, and the result of all their investigations has been to furnish us proof that at one time all the northern half of Europe, Ireland included, must have been covered with an immense cap of slowly-moving ice, of which the present snow-fields and glaciers of Scandinavia are but the shrunken remnants; that the ice extended as far south as central Germany; that it filled up the basins of the Baltic Sea and the North Sea and spread itself in a continuous mass over all of Britain north of the Thames and over all of Ireland, a big glacier occupying the hollow of the present Irish Sea. Moreover, they tell us, that in Southern Europe huge glaciers crept downward in all directions from the Alps and Pyrenees, extending outward far, far beyond the limits of the present glaciers there; and that in North America the Arctic snowfield extended as far south as the thirty-ninth parallel of latitude, that is, farther south than the site of the present city of New York.

All this might sound like a fairy-tale, but there is abundant proof that it is all true.

It will be interesting to examine the evidence of its truth in the case of Ireland.

The picture shows rocks near Loo Bridge, Co. Kerry, smoothed by the passage over them of stone-studded ice. Loo Bridge is on the Loo River, a branch of the Flesk, about twelve miles south-east of Killarney town.

Evidence of Glaciation in Ireland.

I. All over the country wherever the overlying clay is removed, the surface of the solid rock beneath is found to be polished, and marked with slight grooves or scratches, nearly all of which, in any locality, run in a particular direction. Not alone that; but, where the rock sides of the valleys are exposed, as along the coasts of Kerry and of Connemara, they too show to be smoothly polished and to bear grooves or **striæ,** as they are called, running in the direction towards the sea. Now, all this polishing and scratching, could only have been effected by the passage of land-ice over the surface of the rock, and between the walls of the valleys. Wherever glaciers and moving ice-fields occur to-day, as in Switzerland and in Greenland, it is found that the rock-sides and floors of the valleys are polished and striated in the same way. The ice, in its passage, carries with it fragments of stone collected from over the rock floor of the country or torn from the higher mountains. These stones have become firmly embedded in the ice—frozen into it in fact—and they scratch the rock over which the ice-mass slowly moves; so when the ice has melted away, the scratched and polished rock-surfaces remain as witnesses to the story of its passage.

II. Again, in many places up and down the country we meet with enormous **stray blocks** of stone, often perched in quite surprising positions. There are among them blocks much too large to have been transported there by man: and in many cases the rock of which they are composed is different from that of the immediate locality, and shows them to have been carried

very far from their parent mass. Such a block, for instance, is Clough More (Cloch Mhór), near Rostrevor. The boulder itself is of solid granite, like that of the mountains above Newry, but the hillside on which it rests is formed of slate-rock. The boulder is twelve and a half feet long, and nine feet high. It is calculated to weigh over forty tons. The only

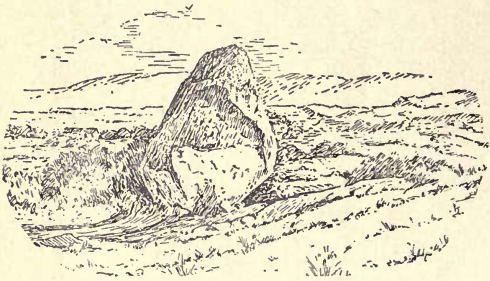


PLATE XIX.—Ice-borne Boulder near Nairn, Co. Donegal.

explanation of how it could have been transported to its present position is that it must have been borne there by moving ice, and left stranded when the ice melted away. Blocks like Clough More are met with in the Alpine regions, where the glaciers have recently retreated, and in Switzerland one can see such blocks being carried along by existing glaciers, on whose surface they have fallen from the overhanging peaks higher up the mountain valley. In Ireland these great boulders are so common, and are found perched in such extraordinary positions, that their presence alone would almost be sufficient proof that glaciers once covered the land.

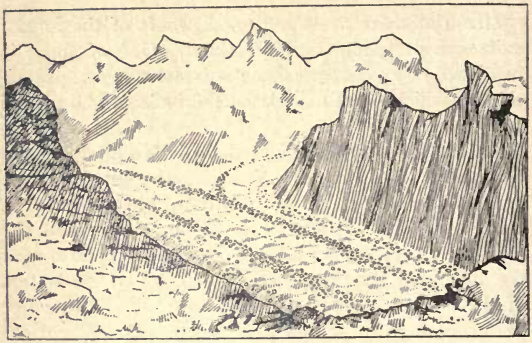
III. But there are other good proofs of the former existence of glaciers over Ireland. One of these is furnished by the presence of **eskers** or gravel-ridges, which must have been the beds of sub-glacial streams.

Beneath existing glaciers there is always a stream of muddy water running. Where the glacier ends, one will notice at its base an arch, where the ice is melted away by this stream. Also, the bed of the stream is piled up with loose stones, dropped out of the melting ice, and rounded to gravel by the action of the stream itself. If the climate were to become warm enough to cause the whole glacier and its parent snow-field to melt, a ridge of gravel would remain to mark where once the sub-glacial stream flowed.

Such gravel ridges, now overgrown with grass, are common in Ireland. In some districts they are called *green-hills*, and in others *eskers*. So common indeed is their occurrence over the country that the word *Esker* (Irish, *Eiscir*) occurs as the name of thirty different townlands in all; and it enters, besides, in combination with other words, into the names of many others. Garrisker, for instance, in County Kildare, gets its name from the Irish *Gearr-Eiscir*, that is, "short gravel-ridge."

A good esker can be seen in South-west Tyrone, and quite a long one runs right across the Central Plain from Clarinbridge in Galway, almost to Dublin. This long ridge is called in the old books, the *Eiscir-Riada*, that is, "the Gravel-ridge of Chariot-driving," because along it lay the great road connecting the Kingdom of Connaught with Tara, and the kings of old rode over it in their chariots. The "Eiscir-

PLATE XX.—A SWISS GLACIER.



SWISS GLACIER SHOWING MEDIAL AND LATERAL MORAINES.

The loose boulders which strew so many mountain gaps in Ireland, *e.g.*, Dunloe and The Scalp, were once moraines like those in this picture. When the ice melted away they were left stranded where we now find them.

END OF GLACIER SHOWING SUB-GLACIAL STREAM.

The " eskers " or gravel ridges so common in Ireland are but the casts of former sub-glacial streams.

Riada " also served as the ancient boundary between the northern half and southern half of Ireland.

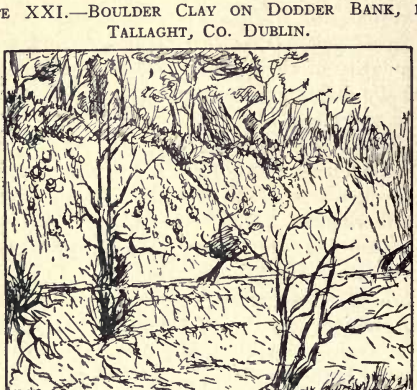
Being grass-grown on the surface, these eskers have the appearance of long, green hills; but often, as at Balrothery, near Tallaght, outside Dublin, they are cut into for use as gravel quarries; and then one can examine their real structure, and see the the similarity of their bedding to the bedding of the gravels in existing sub-glacial streams in the Alps and elsewhere.

IV. Let us look again at our picture of the glacier. We see on either side of the ice-stream a ridge of loose, broken fragments of rock. These ridges are called **moraines.** When the glacier melts, the noraines remain, their rocks being strewn at every angle on either side of the valley once filled by the ice. We are familiar with such rock-strewn valley sides in Ireland—the Gap of Dunloe in Kerry, and the Scalp in County Wicklow, are cases in point—and these valley borders of loose rock, "lateral moraines," as they are called, form another link in the chain of evidence of former glaciation of the country.

Again, when a glacier has travelled far down a valley in Switzerland in winter, and then shrinks back in summer, one can know where the winter ending was by noticing a curve of moraine material across the valley further down. Such a curve of loose rock and stone is called a " terminal moraine," because it piled up where the glacier " terminated." Such terminal moraines are common amidst our mountain valleys. They often indeed dam up the valleys, converting them into lakes. The Upper Lake of Glendalough, for instance, was formed in this way, and so were Upper Lough Bray and many of our other

mountain lakes. When the ground which bounds the lower end of these lakes is examined, it is found to consist of rock-débris, such as would be deposited by melting glaciers.

PLATE XXI.—BOULDER CLAY ON DODDER BANK, NEAR TALLAGHT, CO. DUBLIN.



V. But the most important and widespread evidence that Ireland was for a long period under ice is the thick deposit of boulder clay which covers almost the entire country. This clay is different from clay deposited by rivers. For the most part it is not stratified, that is to say, it does not exist in layers, as river silt would; but it occurs in great masses, often reaching an enormous thickness. Naturally enough, the deposit reaches its greatest thickness in the low grounds and deep valleys of the country, but in

sheltered positions it is sometimes met with at heights of even two thousand feet above sea level. Sometimes it occurs in a series of round-backed elevations called "Drumlins," like the Ards in Down. In the clay are embedded loose fragments of stone of all sizes, sometimes even enormous boulders. That is why it is called **Boulder Clay.** As has been already mentioned, the rock, of which these stones are composed, is often different from that of the rock-floor over which the clay lies. In this way there is much mixing of materials, and the soil is all the richer for the mixing. For example, the limestone fragments existing in the boulder clays of South Dublin and Wicklow form a natural fertiliser in these districts, otherwise lacking in limestone.

The boulder clay itself is fine and powdery, just what would be worn off the rock-floors by the continuous grinding of an enormous mass of stone-studded ice, in its passage over them. In many cases the fragments of stone in the boulder clay are themselves striated. Embedded in the ice they formed grinding tools, which, grooving the surface of the solid rock underneath, also themselves became grooved and striated.

When, with the coming of a milder time, the ice eventually melted away, the clay and stones imprisoned in its lower layers were released, and laid down to form the thick covering of boulder clay which we have noticed all over the country. It is natural to expect that, at the melting of all this ice there must have been torrential floods. The clay must have been washed about, and the stones from it deposited as gravels by the rushing streams. We constantly find, as a matter of fact, irregularly

stratified gravels in connection with the boulder clay. What is more interesting still, we also find in many places two deposits of boulder clay, one above the other, separated by a band of stratified clay, sand and gravel. This seems to point to two lengthy periods of glaciation, with a time of milder climate in between; and geologists think that such must have occurred. They even calculate that there must have been more than one cessation of glacial conditions during the Period which is called the Great Ice Age.

To sum up then—our scratched and polished rock floors and valley sides, our numerous strayed boulders, our many esker ridges, our repeated moraines, and, most of all, our rich deep deposit of boulder clay, and similar evidences met with across the European Continent and North America, place it beyond doubt that Ireland, all Northern Europe, and much of North America, must, since the present land forms took shape, have undergone a prolonged period of glaciation.

When milder times returned, vegetation forced its way back again into the regions whence the ice had retreated. Animals roamed up from the south and penetrated into the virgin country. The Arctic bear, and other Arctic animals, retreated northward with the ice; but the remains of them, which are found in our caves, bear witness to their having once roamed our land.

When the ice passed away for good, the types of life on the earth were almost those with which we are familiar to-day. Man penetrated into the regions of Northern Europe, as the ice shrank back; and he brought with him the animals which he had domesticated in the regions from which he came. The

remains of the dog, sheep, horse and ox are not found in Ireland till after the glacial deposits.

The earliest traces of the presence of man which we find in Ireland are some chipped flints, which occur on the raised beach at Larne. Since that time away back in the dim beginnings of human history, the Irish area has undergone many changes. On the east, the coast at Larne in Antrim, and again at Sutton, near Dublin, has gradually tilted up, so that what were once sea beaches at these places are now far raised above the high-water mark.

Mr. W. B. Wright, of the Geological Survey, has made an exhaustive study of the Great Ice Age; and he considers that this uplift, with the corresponding uplift in Western Scotland is due to the recovery by the earth crust in these areas to its old position from which in glacial times it was crushed down by the weight of the giant mass of overlying ice. The sinking down would have been greatest where the ice-cap was thickest, that would be over Western Scotland; and so the uplift would be most noticeable there, and in the adjoining part of Ireland.

But against this uplift in the east, there has been, since the ice melted away, a sinking of land, or an encroachment of the sea in the West and South-west; what were once glaciated valleys, at Killary Harbour, for instance, and in Kerry and Cork, are now deep-sea inlets, or **fiords**—drowned valleys, in fact.

Again, there is evidence that after the disappearance of the ice great forests sprang up all over the country. Then, there must have come damper times, when marshes became common both in the mountain hollows and in the plains. Peat moss took root in these and throve apace, filling them up with its spongy

vegetation, till it converted them into bogs. The bogs retain evidence of the former forests, for enormous trunks of ancient oak trees are found in them.

At last men penetrated into the country. They found it good to live in; and they made clearings in the forests, and built themselves rude huts of wood and clay, and supported themselves by fishing and by hunting, and by rearing flocks. Later they took to tilling the soil; and from that far-off time even to our own day, the good, rich soil, warmed by the friendly sun, and moistened by kindly showers, has gone on giving up plentiful produce in response to human toil. Succeeding generations of boys have herded cattle on the hill-sides; succeeding generations of strong men have worked on the soil, reclaiming, draining, tilling and manuring it; succeeding generations of women-folk have kept the home, bringing up young families, and going through their endless round of humble duties—spinning, baking, cleaning and stitching. And still, to-day, in spite of the changed conditions of life, in spite of all the centuries of chequered history in between, the boys who herd and the men who till, and the women who keep the country home, are the strongest mainstay of our little land. So, with a tribute to these worthy workers of that soil which the ice, in passing, left as a legacy, we may fittingly end this part of our story.

APPENDIX

APPENDIX

[N.B.—A fairly large coloured Geological Map of Ireland and Great Britain, based on the work of the Geological Survey, is obtainable through any booksellers for two shillings. Also the new edition of the Educational Company's Comparative Atlas contains a coloured Structural Map of Ireland and Great Britain. The student will find that constant reference to one of these maps will greatly help him in his study of Structural Geography.—E. B.]

FOR the convenience of the student, the different Geological Eras with their main sub-divisions, are tabulated in the following pages. They will be found interesting for reference *after the book has been read.* It is hoped that they will help the student by bringing out for him in broad outline the headings of the Annals of the Earth, as they are recorded in the Irish rocks, and repeated in those of Europe.

The student will note that the largest divisions of geological strata are called **Groups,** and that the time taken for the laying down of a Group is called an **Era;** also, that Groups are subdivided into **Systems,** and that the time during which a System was laid down is called a **Period.** Thus, the Mesozoic Group of rocks includes the three Systems: Triassic, Jurassic and Cretaceous; and the Mesozoic Era of geological time includes the three Periods—Triassic, Jurassic and Cretaceous. There are further sub-divisions, but it is unnecessary to burthen the student with them at this stage.

TABLE OF GEOLOGICAL ERAS.

[NOTE—In reading this and the following tables the student must begin from below.]

ERA	PERIOD
Quartary Era (*i.e.*, Fourth Era), also called Human Era	Recent and Post-Pliocene or Glacial
Cainozoic Era (*i.e.*, Era of Recent Life), also called Tertiary Era	Pliocene (*i.e.*, more of recent) Miocene (*i.e.*, less „ „) Oligocene (*i.e.*, a few „ „ Eocene* (*i.e.*, dawn „ „)
Mesozoic Era (*i.e.*, Era of Recent Life)	Cretaceous Jurassic Triassic
Palæozoic Era (*i.e.*, Era of Ancient Life)... ...	Permain Carboniferous Old Red Sandstone Silurian (Upper) Silurian (Lower) Cambrian
Archæan Era (Sedimentary rocks now greatly altered and showing no very distinct traces of organic things)	Unestimated Pre-Cambrian Periods

* The names of the Periods in the Cainozoic Era are based on the number of existing Molluscan species found in each system.

PALÆOZOIC ERA, OR ERA OF ANCIENT LIFE.

The fossil remains of this Era show only the most ancient forms of organic things; in the plant world sea weeds, tree ferns, and club mosses; in the animal world; molluscs, shell fish, scorpions; and types of fish now extinct. Towards the end of the Era, in the Permian Period, or perhaps late in the Carboniferous, reptiles begin to appear.

The entire rock foundations of Ireland, except a small portion in the North-east, were laid down during this Era, all the Irish mountain chains were uplifted, if we except the Antrim and Derry plateau, and the younger Mournes. That is to say the chief structural features of the country date from the Palæozoic Era. To this Era also belong the mountains of Wales, Scotland and the Scandinavian Peninsula, and the mountains of the east of Australia, and of the east of North and South America.

PALÆOZOIC ERA AND GROUP.

Period and System	Occurrence in Ireland	Notable occurrence in Europe	Earth Movements
Permian ...	Holywood, Co. Down. Stewartstown ; Armagh.	Province of Perm in Russia.	East and West foldings.
Carboniferous	Limestone of the Central Plain and of the Southern and N. Western valleys. The Coal Measures	Coal Measures of Great Britain and of Germany.	
Old Red Sandstone	Munster Mountain Ranges ; from Enniskillen across Co. Tyrone to near Cookstown.	Devonian Peninsula ; Brittany and Central France.	North East and South West foldings.
Silurian ... Upper	From Cavan N.E. to the sea at Down.	Gothland Island ; Wales ; Southern Scotland, &c.	
Lower	Rocks flanking the Granite of the Leinster Chain	West and North Midlands of Wales.	
Cambrian ...	Bray Head ; Howth ; South East Wexford.	Isle of Man ; North Wales ; Bohemia.	

MESOZOIC ERA, OR ERA OF MIDDLE LIFE.

The fossil remains of this Era show little development in plant life till about the middle of the Cretataceous Period, when flowering plants appear, and modern trees begin to replace the old tree-ferns and conifers. In the animal world lowly mammals appear in the Trias, but they remain lowly all through the Era. Reptiles flourish most during the Era. In the Jurassic Period they have assumed enormous proportions. Some of these giant creatures crawl the earth, some wade in the streams, some take to the air, and some to the sea; so there are fossil remains of flying reptiles and swimming reptiles. Birds begin to appear late in the Jurassic Period, but they are toothed, and so somewhat different from the birds of to-day.

All three Periods of the Era are represented in the small north-east corner of Ireland.

MESOZOIC ERA AND GROUP.

Period and System	Occurrence in Ireland	Notable occurrence in Europe	Earth Movements
Cretaceous ...	"White Limestone" underlying Basalt of Antrim and Derry Plateau.	Chalk of South East of England and of Northern France. Crete Island.	Subsidence admits Sea into North East Ireland, and probably over much of the Irish Area.
Jurassic ...	Clay beds underlying Chalk exposed here and there round edge of Antrim and Derry Plateau.	Flanks of Jura Mountains. In England from Portland Bill North East through the Midlands to Humber Mouth, and again in the Cleveland Hills.	
Triassic ...	New Red Sandstone round Belfast Lough. Salt and Gypsum at Carrickfergus. Gypsum near Kingscourt.	Chester—New Red Sandstone and Salt deposits.	North East Ireland an arid plateau.

CAINOZOIC ERA, OR ERA OF RECENT LIFE.

The fossil remains of this Era show a plant life approaching nearer and nearer to that of our own time: for instance, the oak tree appears in the Miocene Period. In the animal world the huge reptiles of the previous Era dwindle, and almost die out. On the other hand, mammalian forms, which had remained so undeveloped since their first appearance in the Trias, now show signs of rapid development; and, like the reptiles of the previous Era, some of them, *e.g.*, bats, take to the air, and some, *e.g.*, whales, take to the sea.

It was early in this Era that the Basalt flows occurred, which gave us the Giants' Causeway and the basalt of the Antrim and Derry plateau; later in the Era the sea entered round Donegal, and Ireland became severed from the ancient continent to the North-west, and later still from Great Britain; but the sedimentary rocks of the Era are very little represented in Ireland. However, it may interest the student to see the Era tabulated like the others, the gaps being filled in from the records in European rocks.

It will be remembered that Europe as a continent only exists since the Cainozoic Era, and that it was in that Era that all the present great mountain systems of the world, Alps, Himalays, Rockies and Andes were uplifted.

CAINOZOIC ERA AND GROUP.

Period and System	Occurrence in Ireland	Notable occurrence in Europe	Earth Movements
Pliocene ...	Lough Neagh Clays.	East Norfolk and Suffolk.	Lava flows of Basalt in Auvergne.
Miocene ...	(Not represented in Ireland nor in Great Britain.)	North Italy, Austria, Switzerland, France.	Old continent N.W. of Donegal founders and sea flows in. Alpine Foldings.
Oligocene ...	Aluminium and Iron Ores form on surface of Lower Basalt between the Basalt flows.	London Clay and Clays of Paris Basin.	Earth fractures and basalt flows in North East Ireland, Inner Hebrides and Faröe Islands.
Eocene ...			One of the subterranean cauldrons of this time gave us the "young" granite of the Mournes.

QUARTARY OR FOURTH ERA; ALSO CALLED THE HUMAN ERA.

It is now usual to classify, in a Group apart, all the deposits laid down since the end of the Pliocene Period, that is, since the beginning of Glacial times, and to call the time during which they were laid down, the Quartary* (that is, "fourth") Era. The Era is also named the Human Era, as it roughly corresponds to the time since traces of the presence of man, *e.g.*, flint implements, etc., were embedded in the strata. However, no hard and fast line of division can be drawn, for it is obvious that man may have been present in some parts of the earth long before he reached other parts.

The presence of man has made important differences in the later geological record, especially in the matter of distribution of flora and fauna. Man has cleared forests, drained marshes, killed off many animals, domesticated and changed the habits of many others. He has improved breeds of animals by crossing and selection till they became hardly recognisable; he has cultivated wild fruits till the crab became an apple, and the sloe, a plum. He has cultivated wild flowers till the wild rose yielded the proudest flower of our gardens and till the heart's-ease begat the welcoming pansy. He has brought plants and animals from continent to continent. Sometimes he has changed the face of the flora of a whole district, as when he brought the rubber tree from the Amazon basin to plant it in the Congo and Malay,

* The word is still sometimes written "Quarternary."

where it now occupies whole forests. Potatoes, which he brought from Virginia, are now a staple growth in most European countries.

Of course, the land is always being worn down as before, sediments go on being deposited by the waters as they were before any living thing occupied the earth, continents go on shifting, seas go on encroaching, land goes on uplifting here, sinking there, earthquakes and volcanoes go on making catastrophic changes in parts of the earth crust; and all these happenings are scarcely affected by the presence of man. Yet, in view of the difference which his presence has made in the matter of distribution of plants and animals, and in view of the human interest attached to the period, it seems reasonable to classify the time since the coming of man in an Era apart, even though that time looks insignificant in comparison with the length of the other geological Eras. (See table, page 92.)

This Era gave to Ireland the thick covering of Boulder Clay, which helps to make her such a rich agricultural country; and to this Era also belong our peat bogs.

QUARTARY OR HUMAN ERA.

Period and System	Occurrence in Ireland and in Europe	Earth Movements
Recent and Post Pliocene	Alluvium, river gravels, deltas, bogs; Boulder Clay, moraines, eskers, raised beaches.	Elevation after glacial times in East Ireland & West Scotland. Subsidence in South and West of Ireland.

100—	—Present time	This table shows roughly what geologists now believe to be the approximate relative length of the different Eras, the computation being made on a world-wide basis. It will be seen that the Human Era occupies about one hundredth ($\frac{1}{100}$) of the time which has elapsed since the laying down of the deposits which contain the first well-marked traces of organic things.
99—	—Beginning of Human Era	
75—	—Beginning of Cainozoic Era	
50—	—Beginning of Mesozoic Era	
0—	—Beginning of Palæozoic Era	

Earlier still than the beginning of the Palæozoic Era many systems of sedimentary rocks were laid down representing unestimated Pre-Cambrian Periods. Up to the present, however, no well-defined traces of organic things have been discovered in Pre-Cambrian Rocks.

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